Technical Document F

Part 2: Non-Dwellings Minimum Energy Performance and Building Envelope

Requirements

Effective 1st July 2024

Technical Document F

Part 2: Non-Dwellings

Minimum Energy Performance and Building Envelope Requirements

Building & Construction Authority, Malta

Preamble

This technical document establishes minimum energy performance requirements applicable to new and renovated non-residential buildings intended for human occupancy. The document is divided into two main sub-sections. The first defines the minimum energy performance requirements for the overall building. The second defines renewable energy and the minimum specifications for building elements.

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SCOPING

Scope of technical requirements and glossary of terms

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OVERALL ENERGY PERFORMANCE REQUIREMENTS

Maximum whole building energy performance in kWh/m²a for different non-dwelling categories

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ELEMENTAL REQUIREMENTS

Elemental minimum performance levels requirements, which include:

a. *Thermal transmittance of the individual opaque building elements forming the building envelope;*
b. *Thermal transmittance of glazed elements;*
c. *Solar gains through glazed elements;*
d. *Minimum shading factors.*

(Technical building systems are dealt with in Technical Document F Part 3)

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ON-SITE ENERGY GENERATION REQUIREMENTS

On site energy generation is to provide for a minimum percentage of the energy consumption depending on the dwelling category.
On site renewable energy generation refers to renewable sources such as solar photovoltaic systems, heat pumps, geothermal systems and solar thermal collectors. In conjunction with the building fabric, these shall offer the opportunity to reduce the overall Primary Energy Demand of non-dwellings

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RAINWATER CONSERVATION AND RE-USE REQUIREMENTS

Requirements for rainwater collection and re-use, applicable only to new non-dwellings and renovated non-dwellings having existing water reservoirs

Contents

1. Scoping

I. The minimum requirements for the overall energy performance rating and performance of building elements forming part of the building envelope in non-residential buildings addresses the mandatory requirements for new and renovated buildings, as laid out in Legal Notice 47 of 2018 Energy Performance of Buildings Regulations, as amended by Legal Notice 134 of 2020 or any such law or regulation revoking, amending or replacing it. A compliance checklist in Appendix A summarises the minimum requirements to be met for the building envelope and renewable energy parts.

II. Conservation of fuel, energy and natural resources:
A building shall be so designed, constructed and renovated as to secure, insofar as is reasonably practicable, the conservation of fuel, energy and other natural resources, while contributing to the improvement of internal comfort levels in terms of temperature, humidity and natural lighting to achieve nearly zero energy performance, as required by the Energy Performance of Buildings Directive.

Reasonable provision shall be made for the conservation of energy in a new or renovated building by:

a. As per LN 47 of 2018, as amended by Legal Notice 134 of 2020, limiting the overall energy performance of buildings to nearly zero energy level when calculating the primary energy consumption using the national calculation methodology.
b. Limiting the heat loss in winter and the heat gain in summer through the fabric of the building as required by this technical document.
c. Making use of passive and active measures to maintain comfort levels and good indoor air quality.
d. Incorporating measures to reduce adverse effects of solar radiation, wind and rain while exploiting the benefits of these climatic variables, according to the seasons.

III. Energy generation: provision shall be made for on-site or nearby renewable energy generation through implementation of renewable energy systems such as solar photovoltaic systems, heat pumps and solar thermal collectors, to cover a minimum percentage of the annual primary energy consumption. Where technically not feasible, the additional equivalent contribution from renewable energy installations specifically and exclusively assigned to the building can be considered, subject to the conditions set in Section 2A-2.

IV. Rainwater collection: a new building shall incorporate in its design and construction a reservoir of adequate size for the storage and re-use of rainwater run-off, whilst buildings undergoing a major renovation having an existing water reservoir shall use it for collection and re-use of rainwater.

1.1. Definitions

Assessed object means a building, part of a building or portfolio of buildings that is the object of the energy performance assessment. The assessed object can also be the building unit.

Basement means a storey or storeys of a building located in part or in its entirety below the highest finished pavement level along the street.

Building means a construction as a whole, including its envelope and all technical building systems, where energy may be used to condition the indoor environment, to provide domestic hot water and illumination and other services related to the use of the building. Parts of a building can be physically detached but are on the same building site. For example, a canteen or a guard house or one or more classrooms of a school in a detached part of a building.

Building category means classification of buildings and/or building units related to their main use or their special status, for the purpose of enabling differentiation of the energy performance assessment procedures and/or energy performance requirements.

Building element means integral component of the technical building systems or of the fabric of the building.

Building envelope as defined in LN 47 of 2018 as amended by Legal Notice 134 of 2020 means the integrated elements of a building which separates its interior from the outdoor environment.

Building fabric means all physical elements of a building, excluding technical building systems. E.g.: roofs, walls, floors, doors, gates and internal partitions.

Building service means service provided by the technical building systems to provide the indoor environment conditions, domestic hot water, illumination levels and other services related to the use of the building. This refers to energy used for space heating, space cooling, ventilation, humidification, dehumidification, domestic hot water, lighting and auxiliary.

Building unit means a section, floor or apartment within a building which is designed or altered to be used separately. E.g. a retail outlet in a shopping mall or a rentable office space in an office building. The building unit can be the assessed object.

Curtain wall is a thin, usually aluminium-framed wall, containing in-fills of glass, metal panels or thin stone. The framing is attached to the building structure and does not carry the floor or roof loads of the building.

Exposed building element means an element forming part of the building envelope which is exposed to the external environment.

Energy performance or overall energy performance as defined in LN 47 of 2018 as amended by Legal Notice 134 of 2020 means calculated or measured amount of (weighted) primary energy needed to meet the energy demand associated with a typical use of the assessed object, which includes energy used for specific services (refer to Building service definition). The energy performance is to be calculated according to the national calculation methodology. Also called overall energy performance, to distinguish from partial energy performance.

Floor area means the total area of a building measured to the internal face of the perimeter walls of each floor level including the space occupied by interior walls. Voids over stairwells lift shafts and double height spaces are to be excluded from the calculation, therefore the floor area is measured once at the lowest level only.

Footprint of Land means the area on plan as seen horizontally on a site plan, as measured from the external structure of the property.

Gross exterior wall area means the gross area of exterior walls separating a conditioned space from the outdoors or from unconditioned spaces as measured on the exterior above ground.

NOTE: The gross exterior wall area consists of the opaque wall (excluding vents and grills), including between floor spandrels, peripheral edges of flooring, window areas (including sash) and door areas. The floor-to-floor height is considered, and the thickness of the roof slab is excluded. This definition is applicable for calculating the window-to-wall ratio. However, for the purpose of calculating other parameters for the national calculation methodology, its respective guidance is to be applied.

Nearby renewable energy installation means an installation on other premises that may or may not belong to the same building owner, but which is specifically owned by the building under consideration and exclusively and contractually assigned to it for the whole duration of the building's design lifetime.

Non-exposed floors means floors that are not directly exposed to the external environment. E.g. Floor slab in direct contact with the ground or internal floor separating a thermally conditioned space from an unconditioned space.

Occupied space (zones and rooms in a building) means a space that is intended to be occupied by the same person for a substantial part of the day (30 minutes or more). This excludes circulation spaces and other areas of transient occupancy, such as toilets, as well as spaces that are not intended for occupation (e.g., display windows).

On-site means premises and the parcel of land on which the building(s) is located and the building itself.

Opaque elements in relation to elements exposed to the external environment means those elements which are not rooflights or other openings whether glazed or unglazed.

Orientation means direction a building envelope element faces, i.e. the direction of a vector perpendicular to and pointing away from the surface outside of the element.

Party wall means a wall which serves to separate two buildings or a building from a tenement of a different nature.

Primary energy means energy that has not been subjected to any conversion or transformation process. Note: primary energy includes non-renewable energy and renewable energy, if both are taken into account it can be called total primary energy. The renewable energy part will have an opposite mathematical sign to that derived from fossil-fuelled energy. This is measured in kilowatt hour per square metre per annum (kWh/m^2a).

Reference Building means a building that is equivalent to the actual building as per national calculation methodology.

Roof means an external building element which is either horizontal or if sloping has a slope of less than 60 degrees to the horizontal (including open terraces and any other surface exposed to the elements).

Semi-exposed building element means an element separating a thermally conditioned space from one that is thermally unconditioned. E.g. Floor overlying a garage.

Shading reduction factor means the ratio of incident solar radiation onto a window with shading to the same window without shading.

Solar factor means the total solar energy transmittance (g-value), which is the sum of the solar direct and the secondary heat transfer factor towards the inside; the latter resulting from heat transfer by convection and longwave IR-radiation of that part of the incident solar radiation which has been absorbed by the glazing.

Solar heat gain means heat provided by solar radiation entering, directly or indirectly (after absorption in building elements), into the building through windows, opaque walls and roofs, or passive solar devices such as sunspaces, transparent insulation and solar walls.

Technical building systems means technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity generation, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit.

Thermal conductivity means the rate at which that material will pass heat per unit time and is expressed in units of watts per metre per degrees of temperature difference (W/mK).

Thermally conditioned space means heated and/or cooled space.

Thermally unconditioned space means a room or enclosure that is not part of a thermally conditioned enclosed space (and not forming part of the external environment).

Total solar energy transmittance means the total transmitted fraction of the incident solar radiation consisting of direct transmitted solar radiation and the part of the absorbed solar radiation transferred by convection and thermal radiation to the internal environment. Referred to in this document as Solar Factor (g-value).

Useful floor area means area of the floor of a building needed as parameter to quantify specific conditions of use that are expressed per unit of floor area and for the application of the simplifications and the zoning and (re-)allocation rules.

U-value means the thermal transmittance coefficient, that is a measure of how much heat per unit time will pass through one square metre of a structure when the air temperatures on either side differ by one degree. U value is expressed in units of watts per square metre per degree of temperature difference (W/m^2K).

Visible light transmittance (L-solar) is a fraction of the visible spectrum of sunlight, weighted by the sensitivity of the human eye, that is transmitted through a glazed element. L-solar is expressed as a number between 0 and 1.

Wall means a solid element of the building fabric which is either vertical or has a slope greater than 60 degrees to the horizontal.

Water storage is defined as any means that can be used to store water either above or below ground level.

Water reservoir is defined as a cistern or well used to store rainwater.

Window-to-wall ratio WWR (for a particular wall in a specific orientation) means ratio of the fenestration area to the gross exterior wall area.

Zone as described in the national calculation methodology means a physical area within a building that is distinguished from all others in contact with it by differences in one or more of the following: i. the physical boundaries (such as walls) ii. the activity attached to it, iii. HVAC system which serves it, iv. the lighting system within it and v. the access to daylight.

2. Overall Primary Energy Performance

2.1. Overall primary energy performance per building category

The overall primary energy performance, defined as the primary energy needed to meet the energy demand of a building for space heating, space cooling, lighting, ventilation and hot water less any renewable energy generated on site or linked to the building, as calculated by the national calculation methodology shall not exceed the values in **Table 1**.

The approach shall follow a three-step approach in the following **order of priority**.

1. The building's energy performance rating shall not exceed the overall primary energy demand **excluding** renewables (Column A), in order to independently satisfy the "Energy Efficiency First" principle.

2. The ultimate energy performance rating for the building shall not be higher than the overall primary energy demand **including** renewables installed on site (Column B). The scope of this approach is to ensure that renewable energy is integrated as much as possible in the overall design and that inefficiencies are not overly compensated by renewable energy installations.

3. In case that the renewable energy installations on-site does not **fully** satisfy the minimum requirements in Tables 1 and 2 and that all options for on-site renewable energy installations have been exhausted, then an additional nearby renewable energy systems required to achieve the minimum requirements may be considered, provided that a case dispensation is acquired and approved beforehand.

The overall primary energy performance is expressed as the annual energy per square metre of useful floor area of the building.

Table 1: Overall Primary Energy Demand for Buildings kWh/m^{2}a

Building Category	New Buildings		Major Renovations	
	Without RES	With RES	Without RES	With RES*1
Offices	290	220	350	270
Homes for the Elderly	600	480	720	575
Hotels	600	480	780	625
Restaurants	1000	1000**	1200**	1200**
Schools	350	220	400	290
Shops	600	480	750	600
Sports Complexes	600	300	750	375

* The maximum overall primary energy demand energy demand without renewables need to be achieved independently of when renewables are applied based on the "Energy Efficiency First" principle.

** In their majority, restaurants are assumed to have no access to roofs for installation of solar systems.

*1 These values are indicative targets

The above indicated Primary Energy Demands shall be taken as a minimum target, however, should these not be achievable, a report shall be compiled by a recognised and competent warranted professional, explaining why these figures cannot be achieved, and through a calculated exercise, explain what is the best achievable target for each individual scenario. Bridging of the remaining gap in the Primary Energy Demand, between declared and required, at the time of property construction, shall be achieved through communal renewable systems ones these are available.

2.2. Applicability of overall primary energy performance requirements

i. The minimum requirements set out for new buildings in **Table 1 shall be according to those stipulated in LN 47 2018 or subsequent revisions.**

ii. For buildings that accommodate multiple building categories, each individual building unit shall be compliant to the benchmark of energy performance relevant to that particular building category.

iii. Where the use of an existing building Is being altered without the building undergoing a major renovation (change of use only), compliance to the minimum requirements shall be shown by an assessment of the existing building to minimum energy performance requirements in force when the building was constructed.

2.3. Calculation method

i. The maximum primary energy demand shall be calculated according to the national calculation methodology for non-residential buildings for the particular building category.

ii. Where a building element forming part of the building envelope is being replaced or a building is being extended to a degree which may not be described as a major renovation, the building shall not be required to have a minimum energy performance level. However, each new element forming part of the building envelope shall not be exempt from compliance with maximum thermal conductivity requirements as per **Tables 2&3**.

3. Minimum Requirements for the Building Envelope Elements

3.1. General considerations

i. The building envelope of non-residential buildings shall be designed to meet minimum requirements addressing the elemental thermal transmittance of opaque and glazed elements and solar heat gains through glazed areas.

ii. Construction details involving insulating materials shall be designed such that thermal bridges are avoided as much as is practically reasonable and the risk of interstitial condensation is minimised. Particular attention is to be given to details around windows and doors.

3.2. Limiting thermal transmittance through opaque building envelope elements

3.2.1. Maximum thermal transmittance

The calculated rates of heat loss per unit time (U-value in W/m²K) through the opaque parts of exposed elements shall not be greater than those given in **Table 2**. These values apply for all building categories.

Table *2*: Maximum thermal transmittance (U-value) for new and renovated buildings

Table 2: Maximum thermal transmittance (U-values) for new buildings		
Building element	**Maximum U-value, W/m²K**	**Practical Example****
Exposed walls	1.22	230mm skin + 50mm rigid XPS +10mm Air Gap + Dense Plaster will allow up to 20% of façade to be fitted with minimum complaint double glazing aluminium frame apertures
Exposed floors	0.59	200mm slab + 60mm rigid XPS + 25mm (min) screed + 10mm tile
Non-exposed Floors	1.97	200mm slab + 10mm rigid XPS + 25mm (min) screed + 10mm tile
Roofs	0.4	False ceiling + 200mm slab + 80mm rigid XPS + 25mm Loose Aggregate + 100mm screed + membrane felt (no skylight)
*The maximum U-value is the cumulative U-value calculation of the thermal properties of the unconditioned space and the exposed building element. **Only shown for indicative purposes, actual U Values have to be individually calculated. Specific buildups to cater for specific finish types are to be determined by user.		

3.2.2. Applicability of maximum U-Values

The U-values in **Table 2** are applicable for all exposed and semi-exposed building elements as follows and as shown in **Figure 1**:

i. Exposed walls of bathrooms and other sanitary conveniences that form part of the building are to meet the requirements in **Table 2**.

ii. Exposed building elements of the common parts of a non-residential block (e.g. entrance hall, circulation space, stairwell and lift shaft) are to meet the requirements of **Table 2** for new and renovated buildings.

iii. Exposed building elements of plant rooms, storage rooms, garages, or other spaces with no space conditioning system and not internally connected to the main thermally conditioned space are exempt from meeting the requirements of **Table 2**.

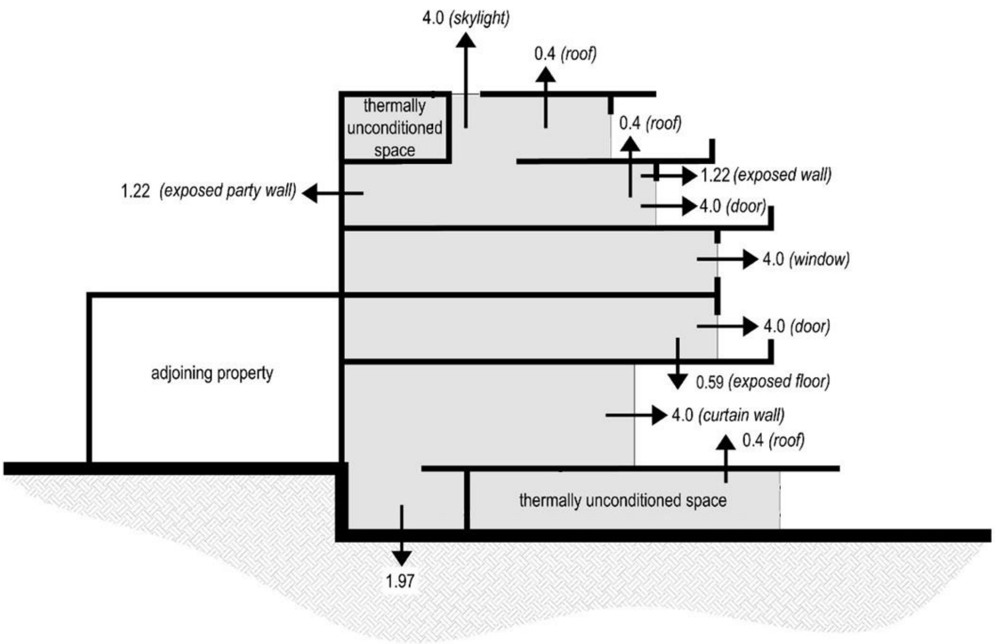


Figure 1: Standard U-values for buildings

3.2.3. Calculation method

U-values calculated using the methods in the standards given below will meet the requirement in this document:

i. The U-value for walls and roofs shall be calculated according to EN ISO 6946.

ii. The U-value of ground floors (including suspended floors directly above the ground) shall be calculated according to EN ISO 13370.

iii. The U-value of basement floors and walls shall be calculated according to EN ISO 13370.

iv. The U-value of a curtain wall system consisting of glazed and opaque panels shall be calculated according to EN ISO 12631.

v. In absence of actual elemental U-values, EN ISO 10456 provides thermal conductivity and density of common building materials from which the U-value can be calculated. For ease of reference these are tabulated in Appendix B. However, data obtained from manufacturers should be given precedence.

vi. When calculating the overall U-value of a specific zone or element consisting of different construction systems the area weighted average U value shall be calculated according to the procedure given in EN ISO 6946 for non-homogeneous layers.

vii. The linear thermal transmittance values and the point thermal transmittance values of thermal bridges shall be taken from tables or catalogues prepared in accordance with ISO 14683 or calculated according to ISO 10211. The overall effect of linear and point thermal bridges should be taken into account when calculating the overall thermal transmittance of the particular building element forming part of the building fabric.

viii. The thermal resistance of an airspace shall be in accordance with EN ISO 6946 as tabulated in section 8.1.

3.3. Limiting thermal transmittance through glazed elements

3.3.1. Maximum thermal transmittance

The calculated overall rate of heat loss per unit time (U-value in W/m²K) through any glazed elements and their frame including roof lights and their supporting structure shall not be greater than the conditions set in **Table 3**.

Table *3*: Maximum thermal transmittance (U-value) for glazed elements in new and renovated buildings

Building element	Maximum U-value, W/m²K (including frame)
Glazed elements	4

3.3.2. Applicability of maximum U-Values

The U-values in Table 4 are applicable for all glazed building elements as follows:

i. The U-value is applicable to the complete window or glazed door system, therefore including both the glass and frame.

ii. Glazed elements in bathrooms and other sanitary conveniences that form part of the building

iii. An external door with more than 1m² of glazing will be treated as a glazed building element.

iv. Glazed building elements of zones and rooms that are not occupied spaces such as plant rooms, storage rooms, and garages, with no space conditioning system and not internally connected to the main thermally conditioned space, are excluded from this requirement.

v. Glazed building elements of the common parts of a complex (e.g. entrance hall, circulation space and stairwell) where internally connected to occupied zones are to meet the requirements of **Table 3** for new buildings and whole complexes undergoing a major renovation. In cases where an individual building unit within a complex is undergoing a major renovation, the common parts are exempt from meeting the requirements of **Table 3**.

3.3.3. Calculation method

i. The U-value of a complete window, door, glazed area or window with shutters is to be calculated according to EN ISO 10077 or tested according to ISO 12567 for complete windows, doors and roof windows. Specifications obtained from manufactures are to be in accordance with these standards.

ii. As specified in ISO 52018-1, the U-value of glazing is to be calculated according to EN ISO 10292 or measured according to EN ISO 10291 or EN ISO 10293

iii. The U-value of a curtain wall system is to be calculated according to EN ISO 12631.

iv. In absence of actual elemental U-values, Appendix C provides indicative U-values for various types of glazed aperture systems. Should these not be provided, default values are to be taken.

v. Display windows in shops and showrooms with single glazed panels protected internally by unheated or uncooled air gap or enclosed internally by draught-proof spaces may be assumed to have a U-value of double glazing for the purpose of these regulations as shown in Figure 2.

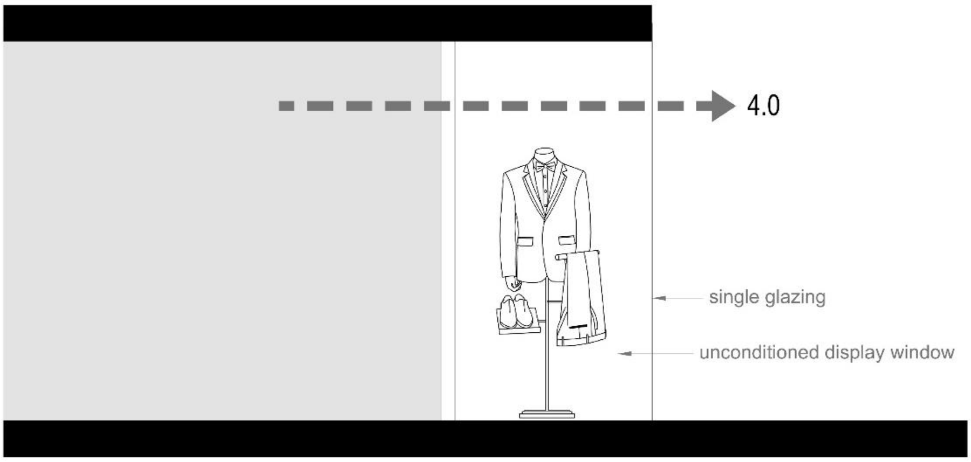


Figure 2: U-value of display windows

3.3.4. Aperture Considerations

i. Apertures must have adequate rubber or equivalent draft sealing characteristics to ensure that air permeation is mitigated, ideally eliminated.

ii. All apertures are to have thermal breaks.

3.3.5. Access doors

Access doors for both new and renovated buildings, separating the exterior from thermally conditioned spaces shall be equipped with either of the following:

i. Automatic sliding doors
ii. Self-closing hinged doors
iii. Draught lobby with automatic doors
iv. Air curtain

3.4. Limiting solar overheating

3.4.1. General considerations

Buildings shall be designed and constructed or renovated such that:

i. Solar gains are controlled by considering optimum orientations when possible, utilising the geometry of the building to provide beneficial shading, strategically positioning and sizing glazed areas, providing external shading devices appropriate to the orientation and through suitable glass specifications.

3.4.2. Minimum requirements for glazed systems

The minimum requirements for glazed systems to control over-heating due to solar radiation are given in **Table 4**. The area of glazing may be increased if shading is provided, or the performance of the glass is improved as explained in Section 3.4.3.

Table *4*: Minimum requirements for unshaded glazed systems in new and renovated buildings

Table 4: Minimum requirements for unshaded clear glazed systems in new and renovated buildings			
Orientation of glazing	**Maximum area of glazing, %** (expressed as a % of the gross exterior wall area of a zone per orientation and assuming 0.2 frame factor)	**Solar factor (g-value) of glazing***	**Visible light transmittance (L-solar)***
N	25	0.76	0.81
S	20	0.76	0.81
NE	17	0.76	0.81
E/SE/SW/NW	12	0.76	0.81
W	9	0.76	0.81
Horizontal	7	0.76	0.81
Note: When the orientation of glazing falls between the compass directions, the compass direction closest to the actual orientation is to be considered. * The solar factor and visible light transmittance are listed here in connection with 3.4.3 design flexibility. These solar factor and light transmittance factors shall be applied when calculating the energy use of the notional building according to 3.4.3.			

3.4.3. Design flexibility

The areas of glazing can be increased provided that the solar energy transmittance through the glass is controlled. This can be done in various ways as described below:

i. Specifying glass to be spectrally selective;
ii. Providing shading devices (externally or mid-pane) parallel to the glass such as venetian blinds, louvers or roller blinds;
iii. Providing shade that is created by the building itself or elements attached to the building such as overhangs and fins.

Additionally, in situations where the building includes glazed areas greater than those stipulated in **Table 4** and shading factors are varied, the requirements below apply:

a. Zone cooling loads ≤ Zone cooling loads if the areas in **Table 4** were applied as reported in the national calculation methodology.

b. Delivered combined energy for heating and cooling ≤ delivered combined energy for heating and cooling if the areas in **Table 4** were applied as reported in the national calculation methodology.

c. Zone heating loads ≤ Zone heating loads if the areas in **Table 4** were applied as reported in the national calculation methodology.

3.4.4. Applicability of minimum requirements for glazed systems

i. The requirements in **Table 4** are applicable to every conditioned zone in the building but excludes zones and rooms that are not occupied spaces and unconditioned zones that are not physically connected to a conditioned zone. This however does not exclude any common circulation spaces that directly lead into occupied zones. Plant rooms and garage areas shall be excluded from the requirements unless these are conditioned.

ii. Shading created by building elements present on the same footprint of land, such as projections and balconies, shall be taken into consideration.

iii. Shading created by objects not within the site's footprint of land shall not be taken into consideration.

3.4.5. Calculation methods

i. If no solar protection device is present, the solar factor, g, of the glazing is determined in accordance with ISO 9050.

ii. If a solar protection device parallel to the glass pane is present, such as venetian blinds, louvers or roller blinds, the combined solar factor for the glass and solar protection device $g_{tot,}$ s determined in accordance to EN ISO 52022, and EN ISO 15099 for a broader range of situations not covered by EN ISO 52022.

iii. Shading reduction factors are to be calculated according to EN ISO 52016-1 or, as a minimum, can be calculated by following the national calculation methodology.

4. Renewable Energy Generation

4.1. Energy generation from photovoltaic systems

4.1.1. Minimum requirements for on-site energy generation

New and renovated buildings shall integrate in their design on-site or nearby renewable energy systems that are statistically, contractually, and exclusively assigned to the building for the whole duration of its design lifetime, to generate a share of the total primary energy, subject to the conditions of Section 2.2. The minimum share of energy generated from photovoltaic systems, or other renewable energy sources that generate electrical energy, varies according to the building category, and is defined by the Renewable Energy Ratio (RER) indicated in **Table 5**.

Table *5*: Minimum requirements for on-site renewable energy generation for new and renovated buildings

Building Category	**RER (as defined in Section 4.1.3)**
Homes for the Elderly	0.01
Hotels	0.01
Offices	0.05
Restaurants	No requirement
Schools	0.15
Shops	0.05
Sports Complexes	0.05

Refer to Appendix B for other building categories that are not listed in **Table 5**.

4.1.2. Applicability

Buildings that have no availability of roof or have limited solar potential shall be exempt from the requirements of renewable energy generation. A report shall be compiled by a recognised and competent warranted professional, explaining why these figures cannot be achieved, and through a calculated exercise, explain what is the best achievable target for each individual scenario. Bridging of the remaining gap in the Primary Energy Demand, between declared and required, at the time of property construction, shall be achieved through communal renewable systems ones these are available.

4.1.3. Calculation method

The Renewable Energy Ratio is calculated as follows:

$$\frac{Renewable\ Primary\ Energy}{Primary\ energy} \geq RER$$

i. The national calculation methodology shall be used to calculate the total and renewable primary energy.
ii. The primary energy shall be calculated in kWh/m²a.
iii. The primary energy takes into consideration energy generated from non-renewable energy sources only for space heating, space cooling, ventilation, domestic hot water, and lighting.
iv. The renewable primary energy takes into consideration energy generated from renewable energy sources only.

4.2. Renewable energy systems for the provision of Domestic hot water

4.2.1. Minimum requirements for renewable energy sources for hot water

In addition to the renewable electricity requirements in Section 4.1, a share of the annual domestic hot water (DHW) energy demand is to be provided by heat pumps and / or solar water heaters and / or CHP as indicated in **Table 6** and **Table 7**.

Table *6*: Minimum requirements for renewable energy sources for hot water for **new** buildings.

Building Category	**RER for domestic hot water**
Homes for the Elderly	0.05
Hotels, Guesthouses and other short term collective accommodation.	0.01
Offices	No requirement
Restaurants (≥ 150 m²)	0.05
Schools	0.05
Shops	No requirement
Sports Complexes	0.05

Refer to Appendix B for other building categories that are not listed in **Table 6**.

Table *7*: Minimum requirements for renewable energy sources for hot water for buildings undergoing **major renovation**.

Building Category	**RER for domestic hot water**
Homes for the Elderly	No requirement
Hotels, Guesthouses and other short term collective accommodation.	0.01
Offices	No requirement
Restaurants (≥ 150 m^2)	0.05
Schools	0.05
Shops	No requirement
Sports Complexes	0.05

Refer to Appendix B for other building categories that are not listed in **Table 7**.

4.2.2. Applicability

i. Minimum requirements for restaurants apply only when the total internal floor area ≥ 150 m².

ii. Minimum requirements for schools undergoing a major renovation are applicable when sports and shower facilities for use by the general public is accommodated.

4.2.3. Calculation method for new buildings

The renewable energy ratio for domestic hot water is calculated as follows:

$$\frac{DHW\ demand - Final\ DHW\ consumption}{DHW\ demand} \geq RER$$

i. The national calculation methodology shall be used to calculate the DHW demand and final DHW consumption.

ii. The DHW demand and final DHW consumption shall be calculated in kWh/m²a.

iii. The domestic hot water demand shall be calculated with equipment having an SCOP of 1.

iv. When a heat pump is used as a renewable energy source for hot water, the renewable energy contribution is equivalent to the difference in energy consumption between a system with a COP of 1 and the COP of the heat pump installed.

v. Losses including distribution and storage losses in pipes and/or ducts and/or tanks should not be considered in the calculations. This requirement does not exempt compliance from the requirement to insulate tanks, pipes and ducts as per Technical Document Part 3 – Minimum Energy Performance Requirements for Technical Building Systems in Malta.

vi. The final DHW consumption shall be calculated considering the new, to be installed DHW system containing SWH and/or heat pumps.

4.2.4. Calculation method for buildings undergoing major renovation

The renewable energy ratio for domestic hot water in the case of renovations is calculated as follows:

$$\frac{Initial\ DHW\ consumption - Final\ DHW\ consumption}{Initial\ DHW\ consumption} \geq RER$$

i. The national calculation methodology shall be used to calculate the initial DHW consumption and final DHW consumption.

ii. The initial DHW consumption and final DHW consumption shall be calculated in kWh/m²a.

iii. The domestic hot water demand shall be calculated with the heat generator element having a SCOP of 1.

iv. Losses including distribution and storage losses in pipes and/or ducts and/or tanks should not be considered in the calculations.

v. The final DHW consumption shall be calculated considering the new, to be installed DHW system containing SWH and/or heat pumps.

5. Minimum Requirements for Conservation and Re-use of Rainwater

Within the Maltese context, rainwater is a valuable resource that significantly contributes towards sustainability and water independence. Moreover, freshwater production and wastewater treatment come at a high cost for the country and require substantial infrastructure and resources.

In light of these constraints, the following requirements in this section shall apply to:

1. All new buildings and buildings undergoing major renovation.

2. All existing buildings undergoing/requesting reinstatement of basic services for water and sewerage shall not be granted such until proof is shown that the current installation does not have a connection between any source of rainwater collection and the sewerage.

3. All other buildings not falling under the Energy Performance of Buildings Directive such as but not limited to factories, farms, service stations, places of worship, historical sites, military facilities that are undergoing major renovation or reinstatement of basic services for water and sewerage.

Rainwater overflows from reservoirs or runoffs from roofs or any other rainwater catchment surfaces (shafts, yards, unroofed balconies, open terraces), shall NOT be connected to the drainage system. This does not preclude property owners from other legal obligations where catchment area is subject to catchment of any form of substance (fluid or solid) that may cause harm if released to surface runoff or water harvesting systems.

Special case scenarios for new and existing buildings having planning permits prior to this version of Document F:

1. For new buildings or existing buildings undergoing a structural alteration that gives a new opportunity for the incorporation of rainwater storage, the provisions of Technical Document F version at the date of the submission of the building development application to the Planning Authority shall apply.

2. For existing buildings, where the owners would like to amend their original legal obligation with regards to rainwater storage in force at the time when the building was constructed, i.e. from the previous legal provisions to the latest provisions of Technical Document F.

Case dispensation (exemption) based on technical justifications may apply, as per the provisions of the Building and Construction Authority Act.

5.1. Minimum size of rainwater reservoirs and reservoirs in new buildings

New Buildings

i. All **new** buildings are to incorporate water reservoirs for collection and storage of rainwater. The minimum size of the reservoir is indicated in **Table 8** and depends on the intended use of the rainwater collected.

ii. Primarily, a second-class water system shall be installed, and this shall cater for toilet flushing, washing machine supply, bib taps intended to dispense water for cleaning purposes, and for irrigation.

iii. Intermittent use is where the water reservoir is predominantly used for irrigation purposes. Whilst this scenario is being factored in, this is still not the desirable route as it will still result in excessive water being diverted to surface runoff and larger carbon footprint to excavate a larger reservoir.

Table 8: Minimum size of water reservoir

Building Type	**Column B: Constant use of collected rain water (m^3)**
All Building Roofs	Total roof area (m^2) x 0.45m
External paved areas (including open terraces and balconies)*	Total paved area (m^2) x 0.45m
***Note:** This requirement applies only to total exposed areas equal to or larger than the concessions indicated in Section 5.2.2. Areas occupied by soil or planters are excluded from the calculation of such area.	

Major Renovation/Existing Buildings

i. All **existing** Buildings that have an existing water reservoir are to collect rainwater and re-use it as indicated in 5.1. ii). If an existing building undergoing major renovation has no water reservoir, but originally had a legal obligation to do so, this shall become compliant to the current Technical Document F requirements. If there are technical issues that prohibit the construction of such a water reservoir the responsible architect shall apply for a case dispensation with the competent authority. **For all cases, connections of rainwater overflows and runoffs shall not be connected to the public sewer system.**

ii. If the existing reservoir is smaller than that indicated in **Table 8,** and cannot be enlarged, or excavated, the property owner has to consult a professional to file in for an exemption following a proper due diligence and factual reasons for exemption.

iii. In a commercial premises tenanted by multiple businesses, the rainwater collected shall be used by at least one of the building units, ideally by all units.

iv. Rainwater does not necessarily have to be collected in an underground reservoir, but one can choose to collect it in above ground structures/containment systems, as long as these are properly sealed and well maintained such that the structure or 3rd party damage is not incurred, such as the utilization of tanks alongside a ring road.

In General: In order to better guide the general public on sizing, **Table 8** indicates the bare minimum. It might be the case that the particular exigencies of the building/premises require large volumes of water to cater for industrial processes or particular operational requirements. It is suggested that proper sizing is designed in line with these exigencies and not on the minimum requirements.

5.2. Collecting areas for new buildings and existing buildings that require the use of a water reservoir

5.2.1. Rainwater that falls on roofs

Rainwater that falls on roofs shall not be allowed to drain into the public sewer or onto a public space or thoroughfare but shall be collected in a suitable reservoir within the building site. Such reservoirs shall have an overflow facility which will prevent the volume of water collected from exceeding the reservoir design capacity. The overflow shall drain to a public place, thoroughfare or underground public rain collection system where the latter is available.

5.2.2. Rainwater that falls on external paved areas

A concession will be allowed to drain up to **20m² per multiple tenanted building** from the external paved areas (such as a balconies) onto a public thoroughfare, provided this does not create a nuisance. This shall be allowed since diverting such contaminated rain water to a common catchment can result in the deterioration of the water reservoir quality (such as draining balconies exposed to detergent use). Areas occupied by soil or planters may be excluded from the calculation of such area.

A concession will be allowed to drain up to **30m² per singularly owned building,** from the external paved areas, (such as balconies) onto a public thoroughfare, provided this does not create a nuisance. This shall be allowed since diverting such contaminated rain water to the water catchment can result in the deterioration of the water reservoir quality (such as draining balconies exposed to detergent use or small roofs used as washing areas). Areas occupied by soil or planters may be excluded from the calculation of such area.

In general, where possible, it is also suggested, to make use of permeable pavement solutions which seeps to ground or is collected by an underlying reservoir. Green roof solutions can also be sought, which in turn also help in reducing energy consumption by insulating the building.

5.3. Provision for the re-use of rainwater

A separate water circulation system together with associated draw off points is to be provided to use collected rainwater for non-potable uses. Such uses include all or any of the uses listed below:

- Irrigation
- Flushing of toilets
- Laundry
- Washing of outdoor areas
- Industrial processes

A distinction is made between use of rainwater for **irrigation purposes** and the use of rainwater for **other purposes**. The former results in an intermittent use of water whilst the later results in a constant use. For this reason, the intended use shall determine the minimum size of the reservoir as explained in section 5.1.

In those buildings with multi-owner occupancies, the provision of second-class water shall be provided to at least one of the occupancies at ground level.

5.4. Design considerations

i. The use of rainwater shall be in accordance with the guidelines set out by the Regulator for Energy and Water Services.
ii. Where it is necessary to introduce rainwater pipes within buildings they shall be completely accessible and shall not be embedded within walls or passed through inaccessible wall cavities.
iii. Rainwater shall be led through an interception trap consisting of one or more chambers designed to settle out pollutants from the rainwater prior to its being stored or disposed elsewhere.
iv. Where rainwater is taken from an area in which fossil fuel or oil are prevalently located, then an oil/water interceptor is to be installed as the collecting gully and the water led away to its final destination.
v. A complete and functioning rainwater distribution system shall be installed.
vi. Safe access for inspection and cleaning of the reservoir is to be provided by means of suitable non-ferrous step irons, ladders or steps incorporated into the structure.
vii. Wells in multiple tenanted buildings can be subdivided
viii. Wherever possible, submersible pumps shall be used to directly supply the second-class water system such that stagnant water is not stored, especially since it is void of disinfectant. Should this not be feasible, a small tank of not more than 200 litres should be used. Same principle

applies for storage of mains water on roofs, which can also be reduced to 200 litres, if not eliminated completely.

ix. Wherever possible, following a proper analysis carried out by professionals, prior to the water reservoir overflowing into the street, one can consider not waterproofing the upper portion of the well. This will give the opportunity for rainwater -to seep directly into the ground, before overflowing into the streets. This is being considered since the water held up in the reservoir has a low risk of contamination from the domestic catchments being considered.

x. Low flow faucets, low flow fittings or faucet aerators shall be incorporated to reduce the water demand. This will also result in a reduction on the energy demand, especially of hot water is being dispensed.

xi. Care should be taken for showerheads not to dispense more than 7 litres per minute, hand wash faucet not more than 5 litres per minute and kitchen faucet not more than 6 litres per minute.

xii. Toilets shall have a dual flush system

xiii. Water consuming appliances being installed such as dishwasher and washing machines shall have a class efficiency of not less than **Class B** in an effort to reduce water and energy consumption.

Appendix A – Building Envelope Checklist

SECTION	CLAUSE	THEMATIC AREA	COMPLIANCE CHECK
Section 2	2.1	Overall Energy Performance	**Energy performance:** The maximum overall primary energy performance is ≤ the values in Table 1 for new buildings and for renovated buildings.
Section 3	3.2.1, 3.3.1	Elemental Requirement	**U-values of opaque and glazed elements:** The U-value for individual building elements for new and renovated buildings is ≤ the values in Table 2 and Table 3.
Section 3	3.3.5	Elemental Requirement	**Access doors:** Closing mechanism for external access doors is automatic or self-closing, if not an air curtain is present.
Section 3	3.4.2	Elemental Requirement	**Limiting solar overheating:** The area of glazing per zone is ≤ the values in Table 4 where no solar control measures are introduced.
Section 3	3.4.3	Elemental Requirement	**Limiting solar overheating, design flexibility:** The area of glazing per zone is > the values in Table 4 but: a. the zone cooling loads are ≤ the zone cooling loads if the areas in Table 4 were applied. b. Delivered combined energy for space heating and cooling ≤ delivered combined energy for heating and cooling if the areas in Table 4 were applied. c. Zone heating loads ≤ Zone heating loads if the areas in Table 4 were applied.
Section 4	4.1.1	On-Site Energy Generation	**Renewable energy sources:** Energy generated from on-site PV systems as a share of the annual primary energy consumption ≥ the values in Table 5.
Section 4	4.2.1	On-Site Energy Generation	**Domestic hot water:** Energy generated from on-site renewable sources specifically for domestic hot water as a share of the annual hot water demand ≥ the values in Table 6 for new buildings and ≥ the values in Table 7 for buildings undergoing major renovation.
Section 5	5.1	Conservation and re-use of rainwater	**Water reservoir for new buildings:** The size of the water reservoir is ≥ minimum size indicated in Table 8 for new buildings.
Section 5	5.1	Conservation and re-use of rainwater	**Water reservoir for renovated buildings:** Provision for collection and re-use of rainwater in the existing water reservoir is being made.

Appendix B – Building Use Classes

This annex classifies building use classes into the building categories of Technical Document F.

Use Class	Category
Beauty and wellness outlets	Shops
Boutique accommodation	Hotels
Clinics	Offices
Day care centres	Schools
Estate agencies	Offices
Food and drink establishments	Restaurants
Guest houses	Hotels
Gymnasiums	Sports complexes
Hairdressing salons	Shops
Hostels	Hotels
Laundry services	Shops
Libraries	Offices
Leisure outlets including; bars, coffee shops and clubs	Restaurants
Museum	Sports complexes
Palazzino	Hotels
Places of assembly	Sports complexes
Post Office	Offices
Retail sale of goods	Shops
Ticket booth	Offices
Travel agencies	Offices

Appendix C – Thermophysical Properties of Building Elements and Calculation Examples

C-1 Introduction

This annex aims at facilitating the implementation of Technical Document F, by providing indicative thermophysical properties of different building materials, which can be used in cases where the manufacturers’ properties are not available, or the properties of existing materials installed in-situ cannot be determined.

Another purpose of the annex is to provide informative approaches for the most common issues that professionals face for calculating specific properties of building materials. Such approaches are not exhaustive, and the reader is advised to refer to the appropriate standards to have a full picture of the methods used.

In using any of the provided values or guidelines, the user should also consider any necessary engineering and architectural skills to collectively provide a comprehensive evidence-based calculation methodology to support the declarations to be made in the compliance certificates and in conformity with any published national regulations and building codes.

C-2 Symbols and Abbreviations

C-2.1 Symbols and units

Symbol	Quantity	Units	Reference
c_p	Specific heat capacity at constant pressure	J/kg K	EN ISO 10456:2007
R	Thermal resistance	m^2K/W	EN ISO 10456:2007
λ	Thermal conductivity	W/mK	EN ISO 10456:2007
U	Thermal transmissivity	W/m^2K	EN ISO 10456:2007
d	Thickness	m	EN ISO 10456:2007
ρ	Density	kg/m^3	EN ISO 10456:2007
κ_m	Effective thermal capacity	kJ/m^2K	EN ISO 13790
$U_{glazing}$	Thermal transmissivity of glass	W/m^2K	
G_{perp}	Perpendicular solar energy transmittance	---	
L_{solar}	Light transmittance	---	
T_{solar}	Total solar energy transmittance	---	
F	Surface area ratio for air gaps and wall material	---	

C-2.2 Abbreviations

Abbreviation	Definition
AD-L2	Approved Document L2 - Part L - Conservation of fuel and power, UK
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BR 443	Conventions for U-value calculations BR 443, BRE Scotland
CE71 (2004)	Energy Saving Trust, Insulation Material Chart: Thermal properties and environmental ratings CE71 (2004)
DOE	Department of Energy
EPS	Expanded polystyrene
HCB	Hollow concrete block (uncoated)
PF	Phenolic foam
PIR	polyisocyanurate or rigid polyiso foam
PUR	Polyurethane rigid foam
SBEM-mt	Simplified Building Energy Modelling for Malta software database

C-3 Thermophysical Properties of Building Elements

C-3.1 Air spaces

Description	Category	Type	R (m^{2}K/W)	d (m)	λ (W/mK)	ρ (kg/m^3)	c_p (J/kgK)	Details	Source
Air layer, 10mm, wall, roof or floor	Air Layer	AIR SPACE	0.15	0.01	---	1.23	1008	Air layer of 10 mm in a roof, wall or floor	EN ISO 6946
Air layer, 15mm, roof	Air Layer	AIR SPACE	0.16	0.015	---	1.23	1008	Air layer in roof of 15 mm or more (heat flow upwards)	EN ISO 6946
Air Layer, 15mm, wall	Air Layer	AIR SPACE	0.17	0.017	---	1.23	1008	Air layer of 15 mm in a wall	EN ISO 6946
Air layer, 25mm, roof	Air Layer	AIR SPACE	0.16	0.025	---	1.23	1008	25 mm unventilated air layer (heat flow upwards)	EN ISO 6946
Air layer, 25mm, wall	Air Layer	AIR SPACE	0.18	0.025	---	1.23	1008	Air layer in wall of at least 25 mm	EN ISO 6946
Air layer, 25mm, well ventilated, wall	Air Layer	AIR SPACE	0.04	0.025	---	1.23	1008	well ventilated air cavity (25 mm)	EN ISO 6946
Air layer, 25mm, floor	Air Layer	AIR SPACE	0.19	0.025	---	1.23	1008	Air layer in floor of 25 mm	EN ISO 6946
Air layer, 35mm, floor	Air Layer	AIR SPACE	0.17	0.035	---	1.23	1008	35 mm air cavity in floor	EN ISO 6946
Air Layer, 5mm, wall, roof or floor	Air Layer	AIR SPACE	0.11	0.05	---	1.23	1008	5 mm air layer in a roof, wall or floor	EN ISO 6946
Air layer, 50mm, floor	Air Layer	AIR SPACE	0.21	0.05	---		1000	An unventilated air layer in a floor, where principal direction of heat is downwards	EN ISO 6946
Air layer, 50mm, roof	Air Layer	AIR SPACE	0.16	0.05	---	1.23	1008	50 mm unventilated air cavity in roof with upwards heat flow	EN ISO 6946
Air layer, 50mm, wall	Air Layer	AIR SPACE	0.18	0.05	---	1.23	1008	Air layer of 50 mm in a wall	EN ISO 6946
Internal services void, 400mm	Air Layer	AIR SPACE	0.18	0.4	---	1.23	1000	Average R for air layer between intermediate conditioned floors.	SBEM-mt

C-3.2 Doors

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Solid wooden door	Doors	SOLID	0.33	0.05	0.15	740	2400	Solid Oak	Typical value engineeringtoolbox.com
Mild steel (including galvanised steel)	Doors	SOLID	0.00004	0.002	50	7800	450	Mild and galvanised steel	BR443
Aluminium	Doors	SOLID	0.00008	0.002	237	2700	897	Aluminium	Typical value engineeringtoolbox.com
Polyurethane (PU) insulated garage door	Doors	SOLID	1	0.045	0.045	PU foam 40	30	Polyurethane (PU) only	Typical value engineeringtoolbox.com

C-3.3 Floor finishes

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Carpet & Fiber Pad (CP01)	Floor finish	SOLID	0.1	0.01	0.1	20	1000	Carpet with Fibrous Pad	DOE2 (ASHRAE)
Rubber	Floor finish	SOLID	---	variable	0.17	1200	1400	Rubber floor covering	EN 12524:2000
Plastic	Floor finish	SOLID	---	variable	0.25	1700	1400	Plastic floor covering	EN 12524:2000
Underlay, cellular rubber or plastic	Floor finish	SOLID	---	variable	0.1	270	1400	Underlay plastic or rubber floor covering	EN 12524:2000
Underlay, felt	Floor finish	SOLID	---	variable	0.05	120	1300	Underlay felt	EN 12524:2000
Underlay, wool	Floor finish	SOLID	---	variable	0.06	200	1300	Underlay wool	EN 12524:2000
Underlay, cork	Floor finish	SOLID	---	variable	0.05	<200	1500	Underlay cork	EN 12524:2000
Carpet & Rubber Pad (CP02)	Floor finish	SOLID	0.1	0.01	0.1	20	1000	Carpet with Rubber Pad	DOE2 (ASHRAE)
Carpet / textile flooring	Floor finish	SOLID	---	variable	0.06	200	1300	Carpet	EN12524:200
Flooring screed	Floor finish	SOLID	0.12	0.050	0.41	1200	1000	Flooring screed. 50mm is a typical thickness	AD-L2 (2002 Edition)
Limestone in *torba*	Render	SOLID	0.125	0.1	0.8	1300	1000	Limestone in *torba*	SBEM-mt
Parquet	Floor finish	HARDWOOD OAK	0.059	0.01	0.17	740	2400	Hardwood oak 1 cm thick	Typical value engineeringtoolbox.com

C-3.4 Mortar, rendering plaster and finishing

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Mortar in inner leaf	Cement Mortar	SOLID	0.11	0.1	0.88	1750	1000	Mortar in inner leaf or otherwise protected from driving rain	AD-L2 (2002 Edition)
Mortar in outer leaf	Cement Mortar	SOLID	0.11	0.1	0.94	1750	1000	Mortar in outer leaf of wall or otherwise exposed to rain/moisture	AD-L2 (2002 Edition)
Limestone in *torba*	Render	SOLID	0.125	0.1	0.8	1300	1000	Limestone in *torba*	SBEM-mt
Render External, 20mm	Render	SOLID	0.035	0.02	0.57	1300	1000	External render	AD-L2 (2002 Edition)
Polythene	Other	SOLID	0.004	0.001	0.25	500	1000	Polythene vapour barrier	SBEM-mt
Cement particleboard	Particle Board	SOLID	0.043	0.01	0.23	1200	1500	Cement particle board	BS EN 12524
Gypsum, dense, 13mm	Plaster	SOLID	0.03	0.013	0.43	1200	1000	13 mm gypsum	AD-L2 (2002 Edition)
Gypsum, lightweight, 13mm	Plaster	SOLID	0.07	0.013	0.18	600	1000	13 mm layer of gypsum	AD-L2 (2002 Edition)
Gypsum, medium density, 13mm	Plaster	SOLID	0.043	0.013	0.3	900	1000	13 mm gypsum	AD-L2 (2002 Edition)
Plaster, dense	Plaster	SOLID	0.023	0.013	0.57	1300	1000	Dense plasterwork, 13 mm thick	AD-L2 (2002 Edition)
Plaster, lightweight, 13mm	Plaster	SOLID	0.072	0.013	0.18	600	1000	Lightweight plaster	AD-L2 (2002 Edition)
Plasterboard (ceiling)	Plasterbo ard	SOLID	0.062	0.013	0.21	900	1000	Plasterboard (ceiling)	SBEM-mt
Plasterboard (wallboard)	Plasterbo ard	SOLID	0.062	0.013	0.21	900	1000	Plasterboard (wallboard). The 0.21 conductivity value is taken from BR443.	BR 443
Plasterboard acoustic	Plasterbo ard	SOLID	0.051	0.0127	0.25	900	1000	Acoustic or fire-resistant plasterboard	BR 443

C-3.5 Roofs/Ceilings

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Roofing screed	Roof finish	SOLID	0.24	0.100	0.41	1200	1000	Flooring screed. 0.1m is a typical thickness	AD-L2 (2002 Edition)
Concrete Heavy Weight (HW) 0.3m (HF-C11)	Concrete, dense	SOLID	0.15	0.3	2	2243	837	Concrete, Heavy Weight, 0.3m	DOE2 (ASHRAE)
Concrete Heavy Weight 0.1m (HF-C5)	Concrete, dense	SOLID	0.05	0.1	2	2243	837	Concrete, Heavy Weight, 0.1m	DOE2 (ASHRAE)
Concrete Heavy Weight 0.2m (HF-C10)	Concrete, dense	SOLID	0.1	0.2	2	2243	837	Concrete, Heavy Weight, 0.2m	DOE2 (ASHRAE)
Concrete Reinforced 1% steel	Concrete, dense	SOLID	0.043	0.1	2.3	2300	1000	Reinforced concrete, 1% steel	EN 12524:2000
Concrete Reinforced 2% steel	Concrete, dense	SOLID	0.04	0.1	2.5	2400	1000	Reinforced concrete, 2% steel	EN 12524:2000
Concrete roof/floor slab	Concrete, dense	SOLID	0.111	0.15	1.35	2000	1000	Cast concrete	AD-L2 (2002 Edition)
Concrete, dense, 150mm	Concrete, dense	SOLID	0.078	0.15	1.93	2400	1000	Concrete block, high density	AD-L2 (2002 Edition)
Concrete, dense, 75mm	Concrete, dense	SOLID	0.036	0.07	1.93	2400	1000	Concrete block, high density	AD-L2 (2002 Edition)
Concrete, no-fines, 150mm	Concrete, dense	SOLID	0.156	0.15	0.96	1800	1000	0.15m cast no fines concrete	SBEM-mt
Concrete, no-fines, 200mm	Concrete, dense	SOLID	0.208	0.2	0.96	1800	1000	200 mm cast no fines concrete	SBEM-mt
AAC (aerated autoclaved concrete)	Concrete, lightweight	SOLID	0.556	0.1	0.18	600	1000	Autoclaved aerated concrete block	AD-L2 (2002 Edition)
Aerated concrete slab	Concrete, lightweight	SOLID	0.203	0.33	1.626	1297	1000	Aerated concrete slab	SBEM-mt
Lightweight (600 kg/m³) concrete, 100mm	Concrete, lightweight	SOLID	0.455	0.1	0.22	600	1000	Lightweight concrete with density of 600 kg/m³	SBEM-mt
Lightweight (600kg/m³) concrete, 200mm	Concrete, lightweight	SOLID	0.909	0.2	0.22	600	1000	Lightweight concrete block with density of 600 kg/m³	SBEM-mt

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
125mm block ceiling, 50mm topping, single beam	Concrete, medium density	SOLID	0.173	0.175	1.012	2000	1000	0.175m overall thickness concrete block ceiling, single beam	SBEM-mt
150mm block ceiling, 50mm topping, single beam	Concrete, medium density	SOLID	0.189	0.2	1.058	2000	1000	0.2m overall thickness concrete block ceiling, single beam	SBEM-mt
175mm block ceiling, 50mm topping, double beam	Concrete, medium density	SOLID	0.176	0.225	1.278	2000	1000	0.225m overall thickness concrete block ceiling, double beam	SBEM-mt
175mm block ceiling, 50mm topping, single beam	Concrete, medium density	SOLID	0.2	0.225	1.125	2000	1000	0.225m overall thickness concrete block ceiling, single beam	SBEM-mt
175mm block ceiling, 75mm topping, double beam	Concrete, medium density	SOLID	0.2	0.25	1.25	2000	1000	0.25m overall thickness concrete block ceiling, double beam	SBEM-mt
225mm block ceiling, 50mm topping, double beam	Concrete, medium density	SOLID	0.208	0.275	1.32	2000	1000	0.275m overall thickness concrete block ceiling, double beam	SBEM-mt
225mm block ceiling, 50mm topping, single beam	Concrete, medium density	SOLID	0.22	0.275	1.25	2000	1000	0.275m overall thickness concrete block ceiling, single beam	SBEM-mt
225mm block ceiling, 75mm topping, double beam	Concrete, medium density	SOLID	0.22	0.3	1.364	2000	1000	0.3m overall thickness concrete block ceiling, double beam	SBEM-mt
225mm block ceiling, 75mm topping, single beam	Concrete, medium density	SOLID	0.233	0.3	1.29	2000	1000	0.3m overall thickness concrete block ceiling, single beam	SBEM-mt
Concrete, 1800 kg/m³	Concrete, medium density	SOLID	0.088	0.1	1.13	1800	1000	Concrete, density=1800	DOE2 (ASHRAE)
Concrete, 2000 kg/m³	Concrete, medium density	SOLID	0.074	0.1	1.35	2000	1000	Concrete block, medium density, inner leaf, 2000 kg/m3	EN 12524:2000
Concrete, 2200 kg/m³	Concrete, medium density	SOLID	0.061	0.1	1.65	2200	1000	Concrete block, density 2200, inner leaf	EN 12524:2000

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source

Light aggregate block (1400 kg/m^3)	Concrete, medium density	SOLID	0.175	0.1	0.57	1400	1000	Lightweight aggregate concrete block	AD-L2 (2002 Edition)
Precast prestressed hollow core concrete slab 1	Concrete, medium density	SOLID	0.099	0.15	1.515	2105	1000	00.15m thick precast hollow core concrete	SBEM-mt
Precast prestressed hollow core concrete slab 2	Concrete, medium density	SOLID	0.15	0.2	1.333	1291	1000	0.2m thick precast hollow core concrete	SBEM-mt
Precast prestressed hollow core concrete slab 3	Concrete, medium density	SOLID	0.158	0.23	1.456	1651	1000	0.23m thick precast hollow core concrete	SBEM-mt
Precast prestressed hollow core concrete slab 4	Concrete, medium density	SOLID	0.177	0.25	1.412	1513	1000	0.25m thick precast hollow core concrete	SBEM-mt
Precast prestressed hollow core concrete slab 5	Concrete, medium density	SOLID	0.179	0.28	1.564	1616	1000	0.28m thick precast hollow core concrete	SBEM-mt
Precast prestressed hollow core concrete slab 6	Concrete, medium density	SOLID	0.203	0.33	1.626	1297	1000	0.33m thick precast hollow core concrete	SBEM-mt
Limestone in *torba*	Render	SOLID	0.125	0.1	0.8	1300	1000	Limestone in *torba*	SBEM-mt
Roofing screed	Floor finish	SOLID	0.12	0.050	0.41	1200	1000	Flooring screed. 0.5m is a typical thickness	AD-L2 (2002 Edition)

C-3.6 Infills

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Gravel 25mm (RG02)	Roof Gravel	SOLID	0.0125	0.025	2	881	1674	Roof Gravel or Slag, 0.025m	SBEM-mt
Soil, 100mm	Soil	SOLID	0.067	0.1	1.5	1250	2500	Soil, clay or silt	BS EN 12524
Stone chippings 10mm	Stone	SOLID	0.005	0.01	2	2000	1000	0.01m of stone chipping	AD-L2 (2002 Edition)
Stone chippings, 25mm	Stone	SOLID	0.0125	0.025	2	2000	1000	0.025m of stone chippings	AD-L2 (2002 Edition)
Limestone in *torba*	Render	SOLID	0.125	0.1	0.8	1300	1000	Limestone in *torba*	SBEM-mt

C-3.7 Insulation

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Mineral wool batt, 100mm	Insulation (batts)	SOLID	2.632	0.100	0.038	25	1030	Mineral wool batt EN12525 gives Cp=1030	AD-L2 (2002 Edition)
Mineral wool batt, 140mm	Insulation (batts)	SOLID	3.500	0.140	0.04	24	1030	Mineral wool between timber frame, 140 mm deep	DOE2 (ASHRAE)
Mineral wool batt, 50mm	Insulation (batts)	SOLID	1.316	0.050	0.038	25	1030	Mineral wool batt	AD-L2 (2002 Edition)
EPS, 100mm	Insulation (board)	SOLID	2.500	0.100	0.04	15	1300	100 mm of expanded polystyrene insulating board	AD-L2 (2002 Edition)
EPS, 160mm	Insulation (board)	SOLID	4.000	0.160	0.04	15	1300	160 mm of Expanded polystyrene board	AD-L2 (2002 Edition)
EPS, 200mm	Insulation (board)	SOLID	5.000	0.200	0.04	15	1300	200 mm of expanded polystyrene insulation board	SBEM-mt
EPS, 25mm	Insulation (board)	SOLID	0.625	0.025	0.04	15	1300	25 mm of expanded polystyrene insulating board	AD-L2 (2002 Edition)
EPS, 50mm	Insulation (board)	SOLID	1.250	0.050	0.04	15	1300	Expanded polystyrene, 50 mm thick	AD-L2 (2002 Edition)
EPS, 75mm	Insulation (board)	SOLID	1.875	0.075	0.04	15	1300	75 mm of expanded polystyrene insulating board	AD-L2 (2002 Edition)
Extruded polystyrene, 25mm	Insulation (board)	SOLID	0.926	0.025	0.027	40	1450	CE71 says lambda varies from 0.025 to 0.038	BS EN 12524
Extruded polystyrene, 50mm	Insulation (board)	SOLID	1.852	0.050	0.027	40	1300	Extruded polystyrene, 50 mm thick CE71 says that conductivity varies from 0.025 to 0.038.	SBEM-mt
Fibreboard	Insulation (board)	SOLID	0.130	0.013	0.1	400	1000	Fibreboard	SBEM-mt

Description	Category	Type	R (m^2K/W)	d (m)	λ (W/mK)	ρ (kg/m^3)	c_p (J/kgK)	Details	Source
PF	Insulation (board)	SOLID	2	0.050	0.025	30	1800	Phenolic foam board. CE71 suggests that the conductivity for phenolic foam is about 0.025, but falls to about 0.02 if it is foil faced.	AD-L2 (2002 Edition)
PF (foil faced)	Insulation (board)	SOLID	2.5	0.050	0.02	30	1000	Phenolic foam. CE71 suggests that foil-faced phenolic foam has a conductivity of about 0.02	CE71 (2004)
PF (unfaced)	Insulation (board)	SOLID	2	0.050	0.025	30	1000	Phenolic foam	CE71 (2004)
PIR (foil faced)	Insulation (board)	SOLID	2.632	0.050	0.019	30	1000	CE71 gives the conductivity of PIR (foil faced) to be about 0.019	CE71 (2004)
PIR (unfaced)	Insulation (board)	SOLID	2.174	0.050	0.023	30	1000	Polyisocyanurate board insulation (unfaced) CE71 (2004) says that the lambda value varies between 0.022 and 0.023	CE71 (2004)
PUR (foil-faced)	Insulation (board)	SOLID	2.273	0.050	0.022	30	1000	CE71(2004) indicates that a typical conductivity of foil-faced polyurethane is 0.022	CE71 (2004)
PUR, 100 mm, 4in	Insulation (board)	SOLID	3.846	0.100	0.026	30	1800	Polyurethane, Expanded, 0.1m	AD-L2 (2002 Edition)
PUR, 13mm	Insulation (board)	SOLID	0.5	0.013	0.026	30	1800	Polyurethane, Expanded, 0.013m	AD-L2 (2002 Edition)
PUR, 25mm	Insulation (board)	SOLID	0.962	0.025	0.026	30	1800	25 mm of polyurethane insulation board	AD-L2 (2002 Edition)
PUR, 40mm	Insulation (board)	SOLID	1.538	0.040	0.026	30	1800	Polyurethane insulating board	AD-L2 (2002 Edition)

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
PUR, 50mm, 2in	Insulation (board)	SOLID	1.923	0.050	0.026	30	1800	CE71 indicates that a typical conductivity of expanded polyurethane is 0.026. If it is foil-faced, however it is typically 0.022	CE71 (2004)
PUR, 75mm, 3in	Insulation (board)	SOLID	2.885	0.075	0.026	30	1800	Polyurethane, 0.075m	AD-L2 (2002 Edition)
Mineral wool in timber frame	Insulation (fill)	SOLID	2.342	0.089	0.038	25	837	Mineral wool between 89 mm timber framing, typically occupying 15% of the area	AD-L2 (2002 Edition)
Cellular Glass	Insulation (miscellaneous)	SOLID	2.5	0.100	0.04	1	837	Cellular glass	SBEM-mt
Mineral wool, dense, 150mm	Insulation (miscellaneous)	SOLID	2.7	0.100	0.036	50	1030	150 mm Rockwool Hardrock insulation	SBEM-mt
Mineral wool, dense, 70mm	Insulation (miscellaneous)	SOLID	1.944	0.070	0.036	50	1030	70 mm Rockwool Hardrock	Encon Ltd. guide
Roof/wall metal clad insulated panel 1	Insulation (miscellaneous)	SOLID	2.13	0.040	0.02	252.5	1800	40 mm thick metal clad polyurethane (PUR) panel	SBEM-mt
Roof/wall metal clad insulated panel 2	Insulation (miscellaneous)	SOLID	2.56	0.050	0.02	210.1	1800	50 mm thick metal clad PUR panel	SBEM-mt
Roof/wall metal clad insulated panel 3	Insulation (miscellaneous)	SOLID	3.03	0.060	0.02	181.67	1800	60 mm thick metal clad PUR panel	SBEM-mt
Roof/wall metal clad insulated panel 4	Insulation (miscellaneous)	SOLID	3.45	0.070	0.02	161.43	1800	70 mm thick metal clad PUR panel	SBEM-mt
Roof/wall metal clad insulated panel 5	Insulation (miscellaneous)	SOLID	4	0.080	0.02	146.25	1800	80 mm thick metal clad PUR panel	SBEM-mt
Roof/wall metal clad insulated panel 6	Insulation (miscellaneous)	SOLID	4.35	0.090	0.02	134.44	1800	90 mm thick metal clad PUR panel	SBEM-mt
Roof/wall metal clad insulated panel 7	Insulation (miscellaneous)	SOLID	4.76	0.100	0.02	125	1800	100 mm thick metal clad PUR panel	SBEM-mt

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Glass wool, 100mm	Insulation (quilt)	SOLID	2.5	0.100	0.04	12	750	100 mm glass wool (BS 5250)	SBEM-mt
Glass wool, 150mm	Insulation (quilt)	SOLID	3.75	0.150	0.04	12	750	150 mm glass wool quilt (BS 5250)	SBEM-mt
Glass wool, 60mm	Insulation (quilt)	SOLID	1.5	0.060	0.04	12	750	60 mm glass fibre insulation (BS 5250)	SBEM-mt
Glass wool, 75mm	Insulation (quilt)	SOLID	1.875	0.075	0.04	12	750	75 mm of glass wool	SBEM-mt
Mineral wool quilt, 100mm	Insulation (quilt)	SOLID	2.5	0.1	0.04	12	1030	Mineral wool quilt, 100 mm thick	DOE2 (ASHRAE)
Mineral wool quilt, 150mm	Insulation (quilt)	SOLID	3.75	0.15	0.04	12	1030	150 mm mineral wool	AD-L2 (2002 Edition)
Mineral wool quilt, 20mm	Insulation (quilt)	SOLID	0.625	0.025	0.04	12	1030	20 mm of mineral wool quilt insulation	SBEM-mt
Mineral wool quilt, 50mm	Insulation (quilt)	SOLID	1.25	0.050	0.04	12	1030	Mineral wool quilt, 50 mm thick	AD-L2 (2002 Edition)
Mineral wool quilt, 75mm	Insulation (quilt)	SOLID	1.875	0.075	0.04	12	1030	Mineral fibre quilt, 75 mm	AD-L2 (2002 Edition)

C-3.8 Metals

Description	Category	Type	R (m^2K/W)	d (m)	λ (W/mK)	ρ (kg/m^3)	c_p (J/kgK)	Details	Source
Aluminium sheet, 20mm	Metal	SOLID	0.000125	0.020	160	2800	880	20 mm thick cladding panel	EN 12524
Copper	Metal	SOLID	---	---	380	8900	380		EN ISO 10456:2007
Mild steel	Metal	SOLID	0.00002	0.001	50	7800	450	Mild steel. Conductivity either 50 or 60.	BR 443
Mild steel, 5mm	Metal	SOLID	0.0001	0.005	50	7800	450	5 mm steel deck	BR 443
Stainless Steel	Metal	SOLID	0.0006-	0.010	17	7900	1000	Stainless steel	AD-L2 (2002 Edition)
Steel Siding (HF-A3)	Metal	SOLID	0.0002	0.010	45	7689	418	Steel Siding, Light Weight	DOE2 (ASHRAE)

C-3.9 Stones

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Natural crystalline rock	Stones	SOLID	---	---	3.5	2800	1000	Natural crystalline rock	EN ISO 10456:2007
Natural, sedimentary rock	Stones	SOLID	---	---	2.3	2600	1000	Natural, sedimentary rock	EN ISO 10456:2007
Natural, sedimentary rock, light	Stones	SOLID	---	---	0.85	1500	1000	Natural, sedimentary rock, light	EN ISO 10456:2007
Granite	Stones	SOLID	---	---	2.8	2500-2700	1000	Granite	EN ISO 10456:2007
Marble	Stones	SOLID	---	---	3.5	2800	1000	Marble	EN ISO 10456:2007
Slate	Stones	SOLID	---	---	2.2	2000-2800	1000	Slate	EN ISO 10456:2007
Limestone, extra soft	Stones	SOLID	---	---	0.85	1600	1000	Limestone, extra soft	EN ISO 10456:2007
Limestone, soft	Stones	SOLID	---	---	1.1	1800	1000	Limestone, soft	EN ISO 10456:2007
Limestone, semi-hard	Stones	SOLID	---	---	1.4	2000	1000	Limestone, semi-hard	EN ISO 10456:2007
Limestone, hard	Stones	SOLID	---	---	1.7	2200	1000	Limestone, hard	EN ISO 10456:2007
Limestone, extra hard	Stones	SOLID	---	---	2.3	2600	1000	Limestone, extra hard	EN ISO 10456:2007
Artificial stone	Stones	SOLID	---	---	1.3	1750	1000	Artificial stone	EN ISO 10456:2007

C-3.10 Tiles

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Ceiling tile	Tiles / slate	SOLID	0.167	0.015	0.09	250	1000	Typical ceiling tile, conductivity 0.06, 15 mm thick, weight of 3.5 kg per square metre	SBEM-mt
Ceramic tiles	Tiles / slate	SOLID	0.008	0.01	1.3	2300	1000	Ceramic tiles	SBEM-mt
Concrete roof tiles	Tiles / slate	SOLID	0.017	0.025	1.5	2100	1000	Concrete tiles (typically for roof)	SBEM-mt
Linoleum Tile (LT01)	Tiles / slate	SOLID	---	---	0.17	1200	1400	Linoleum Tile	EN12524:2000
Slate, 13mm, 1/2in (SL01)	Tiles / slate	SOLID	0.01	0.01	1	1602	1464	Slate, 1/2 Inch	DOE2 (ASHRAE)
Terrazzo 1in (TZ01)	Tiles / slate	SOLID	0.005	0.01	2	2243	837	Terrazzo, 25mm	DOE2 (ASHRAE)
Tiles (clay)	Tiles / slate	SOLID	0.01	0.01	1	2000	920	Tiles (clay)	SBEM-mt
Tiles, cork	Tiles / slate	SOLID	---	---	0.065	>400	1500	Tiles (cork)	EN12524:2000
Tiles, plastic	Tiles / slate	SOLID	---	---	1.5	2100	1000	Tiles 9plastic)	EN ISO 10456:2007

C-3.11 Walls

Note: The R-value excludes any finishing or surface resistances.

Description	Category	Type	R (m^2K/W)	d (m)	λ (W/mK)	ρ (kg/m^3)	c_p (J/kgK)	Details	Source
115mm thick HCB	Brick	SOLID	0.21	0.12	0.57	1097	1000	115mm in thick HCB, uncoated	SBEM-mt
150mm thick HCB	Brick	SOLID	0.22	0.152	0.69	1291	1000	150mmn thick HCB, uncoated	SBEM-mt
180mm thick HCB	Brick	SOLID	0.23	0.177	0.766	1156	1000	180mm HCB, uncoated	SBEM-mt
230mm double thickness HCB*	Brick	SOLID	0.27	0.230	0.86	1345	1000	230mm double thickness HCB, uncoated	SBEM-mt
230mm single thickness HCB*	Brick	SOLID	0.28	0.230	0.81	1164	1000	230mm single thickness HCB, uncoated	SBEM-mt
HCB 150mm Infilled	Brick	SOLID	0.135	0.153	1.13	1800	1000	Infilled 150mm brick, uncoated	SBEM-mt
HCB 7in Infilled	Brick	SOLID	0.157	0.177	1.13	1800	1000	Infilled 7 in HCB, uncoated	SBEM-mt
HCB 230mm (single or double) infilled	Brick	SOLID	0.204	0.230	1.13	1800	1000	Infilled 230mm HCB, uncoated	SBEM-mt
Limestone, hard, *tal-qawwi* 150mm	Stone	SOLID	0.09	0.15	1.7	2400	1000	Hard limestone	SBEM-mt
Limestone, hard, *Franka* 230mm	Stone	SOLID	0.135	0.23	1.7	2400	1000	Hard limestone	SBEM-mt
Limestone, soft *Franka* 150mm	Stone	SOLID	0.136	0.15	1.1	1800	1000	Soft limestone 150mm	EN ISO 10456:2007
Limestone, soft *Franka* 175mm	Stone	SOLID	0.159	0.175	1.1	1800	1000	Soft limestone 175mm	EN ISO 10456:2007
Limestone, soft *Franka* 230mm	Stone	SOLID	0.209	0.23	1.1	1700	1000	Soft limestone 230mm	SBEM-mt
Sandstone, 150mm	Stone	SOLID	0.065	0.15	2.3	2600	1000	Sandstone	SBEM-mt
Sandstone, *Gebla Ramlija* 230mm	Stone	SOLID	0.1	0.23	2.3	2600	1000	Sandstone	SBEM-mt

* Single and double thickness refers to the thickness of the HCB's web. When the web is thick, the air gap is smaller. Double-thickness HCB does not mean a double-leaf wall and does not comply with the minimum requirements of Technical Document F of U-value of 1.57 W/m^2K, when used alone.

C-3.12 Water-proofing membranes

Description	Category	Type	R (m²K/W)	d (m)	λ (W/mK)	ρ (kg/m³)	c_p (J/kgK)	Details	Source
Asbestos cement, 10mm	Asbestos Cement	SOLID	0.028	0.01	0.36	700	1000	10 mm asbestos cement (BS 5250)	SBEM-mt
Asbestos cement, 5mm	Asbestos Cement	SOLID	0.014	0.005	0.36	700	1000	Asbestos cement sheet (BS 5250)	SBEM-mt
Asphalt, 19mm	Asphalt	SOLID	0.027	0.019	0.7	2100	1000	19 mm of asphalt	EN 12524:2000
Bitumen	Asphalt	SOLID	0.059	0.01	0.17	1050	1000	Pure Bitumen	EN 12524:2000
Bitumen Felt	Felt	SOLID	0.026	0.006	0.23	1100	1000	Bitumen felt or sheet	EN 12524:2000
Felt 3/8in (HF-E3)	Felt	SOLID	0.01	0.010	1	1121	1674	Felt and Memb, 3/8 Inch	DOE2 (ASHRAE)
Felt on flat roof	Felt	SOLID	0.03	0.006	0.2	1100	1000	Typical felt layer on a flat roof, based on the default construction provided by the BRE U-value calculator software	SBEM-mt

C-3.13 Wood

Description	Category	Type	R (m^2K/W)	d (m)	λ (W/m)	ρ (kg/m^3)	c_p (J/kgK)	Details	Source
Fibreboard (medium density)	Wood	SOLID	0.429	0.03	0.07	250	1700	30 mm fibreboard (medium density)	EN ISO 10456:2007
Fibreboard (medium density)	Wood	SOLID	0.3	0.03	0.1	400	1700	30 mm fibreboard (medium density)	EN ISO 10456:2007
Fibreboard (medium density)	Wood	SOLID	0.214	0.03	0.14	600	1700	30 mm fibreboard (medium density)	EN ISO 10456:2007
Fibreboard (medium density)	Wood	SOLID	0.167	0.03	0.18	800	1700	30 mm fibreboard (medium density)	EN ISO 10456:2007
Plywood	Wood	SOLID	0.333	0.03	0.09	300	1600	30 mm floor plywood	EN ISO 10456:2007
Plywood	Wood	SOLID	0.231	0.03	0.13	500	1600	30 mm floor plywood	EN ISO 10456:2007
Plywood	Wood	SOLID	0.176	0.03	0.17	700	1600	30 mm floor plywood	EN ISO 10456:2007
Plywood	Wood	SOLID	0.125	0.03	0.24	1000	1600	30 mm floor plywood	EN ISO 10456:2007
Timber stud, 89mm	Wood	SOLID	0.685	0.089	0.13	500	1500	89 mm timber stud	BS EN 12524
Wood wool slab	Wood	SOLID	0.5	0.05	0.1	500	1000	Wood wool roofing slab	SBEM-mt
Wood, hard	Wood	SOLID	0.278	0.05	0.18	700	1600	Hardwood timber	ISO 10456:2007
Wood, soft	Wood	SOLID	0.385	0.05	0.13	500	1600	Softwood timber	ISO 10456:2007
Wood, soft, 100mm, 4in (HF-B9)	Wood	SOLID	0.769	0.1	0.13	500	1600	Wood, 4 Inch	ISO 10456:2007

C-3.14 Glazing

Description	Category	Type	U_{glass} * (W/m²K)	L_{solar} **	T_{solar} **	G_{perp} **	Source
4mm single glazing (clear glass)	PANES	SINGLE	5.75	0.9	0.85	0.85	EN ISO 10077-1
6mm single glazing (clear glass)	PANES	SINGLE	5.68	0.89	0.82	0.82	EN ISO 10077-1
4 mm Notional building glazing, uncoated	PANES	SINGLE	4.3	0.9	0.85	0.7	EN ISO 10077-1
Rooflight, single skin polycarbonate	PANES	SINGLE	7.1	0.8	0.8	0.8	EN ISO 10077-1
10-16-6 uncoated, air filled	PANES	DOUBLE	3.551	0.8	0.76	0.76	EN ISO 10077-1
10-16-6 low-e, air filled	PANES	DOUBLE	2.858	0.8	0.72	0.72	EN ISO 10077-1
4-16-4 uncoated glass, air filled	PANES	DOUBLE	2.7	0.81	0.75	0.76	EN ISO 10077-1
4-16-4, low-e coated, air filled	PANES	DOUBLE	1.7	0.75	0.72	0.76	EN ISO 10077-1
4-6-4, uncoated glass, air filled	PANES	DOUBLE	3.3	0.81	0.75	0.76	EN ISO 10077-1
4-12-4 uncoated glass, air filled	PANES	DOUBLE	2.8	0.81	0.75	0.76	EN ISO 10077-1
4-20-4, uncoated, air filled	PANES	DOUBLE	2.7	0.81	0.75	0.76	EN ISO 10077-1
4-6-4 low-e, air filled	PANES	DOUBLE	2.6	0.75	0.72	0.76	EN ISO 10077-1
4-12-4 low-e, air filled	PANES	DOUBLE	1.9	0.75	0.72	0.76	EN ISO 10077-1
4-20-4 low-e, air filled	PANES	DOUBLE	1.7	0.75	0.72	0.76	EN ISO 10077-1
4-6-4 uncoated, argon filled	PANES	DOUBLE	3	0.81	0.75	0.76	EN ISO 10077-1
4-12-4 uncoated, argon filled	PANES	DOUBLE	2.7	0.81	0.75	0.76	EN ISO 10077-1
4-16-4 uncoated, argon filled	PANES	DOUBLE	2.6	0.81	0.75	0.76	EN ISO 10077-1
4-20-4 uncoated, argon filled	PANES	DOUBLE	2.6	0.81	0.75	0.76	EN ISO 10077-1
4-6-4 low-e, argon filled	PANES	DOUBLE	2.3	0.75	0.72	0.76	EN ISO 10077-1
4-12-4, low-e, argon filled	PANES	DOUBLE	1.6	0.75	0.72	0.76	EN ISO 10077-1
4-16-4 low-e, argon filled	PANES	DOUBLE	1.5	0.75	0.72	0.76	EN ISO 10077-1
4-20-4 low-e, argon filled	PANES	DOUBLE	1.5	0.75	0.72	0.76	EN ISO 10077-1

Description	Category	Type	U_{glass} * (W/m²K)	L_{solar} **	T_{solar} **	G_{perp} **	Source
Acoustic double glazing with 200mm inter-pane gap uncoated	PANES	DOUBLE	2.9	0.81	0.75	0.8	EN ISO 10077-1
Rooflight, twin skin polycarbonate	PANES	DOUBLE	2.8	0.7	0.7	0.7	EN ISO 10077-1
4-12-4 Notional building glazing, uncoated	PANES	DOUBLE	3.3	0.81	0.75	0.7	EN ISO 10077-1
4-16-4 Notional building glazing, low-e	PANES	DOUBLE	2	0.75	0.72	0.7	EN ISO 10077-1
4-6-4-6-4 air-filled triple glazing, uncoated	PANES	TRIPLE	2.2	0.73	0.67	0.7	EN ISO 10077-1
4-12-4-12-4 air-filled triple glazing, uncoated	PANES	TRIPLE	1.9	0.73	0.67	0.7	EN ISO 10077-1
4-6-4-6-4 low-e air-filled triple glazing	PANES	TRIPLE	1.7	0.66	0.59	0.7	EN ISO 10077-1
4-12-4-12-4 triple glazing, low-e	PANES	TRIPLE	1.2	0.66	0.59	0.7	EN ISO 10077-1
4-12-4-12-4 triple glazing, argon-filled, low-e	PANES	TRIPLE	1.8	0.73	0.67	0.7	EN ISO 10077-1
4-12-4-12-4 triple glazing, argon filled, uncoated	PANES	TRIPLE	1.8	0.73	0.67	0.7	EN ISO 10077-1
Rooflight, triple skin, 12 mm air, polycarbonate 55	PANES	TRIPLE	2	0.5	0.5	0.5	SBEM-MT

* The U_{glass} requires one correction before it can be used for the calculation of heat transfer. This correction concerns the effect of the frame on the overall U value of glass + frame (Table 0 & Table 3.15).

** It is important to note that these values are for the glass pane only. Corrections will need to be applied to cater for the effect of the opaque frame on solar and light transmission.

C-3.15 Correction to Uglass value due to frame

Window type	Frame type	No. of glass panes	U-value adjustment for U_{glass} (W/m²K)
Skylights	Wood or UPVC	Single	+ 0.3
		Double	+ 0.2
		Triple	+ 0.2
	Metal	No thermal break	+ 0.7
		4 mm thermal break	+ 0.3
		8 mm thermal break	+ 0.2
		12 mm thermal break	+ 0.1
		20 mm thermal break	+ 0
		32 mm thermal break	+- 0.1
Windows	Wood or UPVC	Single	+ 0.3
		Double	+ 0.2
		Triple	+ 0.2
	Metal	No thermal break	+ 0.3
		4 mm thermal break	+ 0.0
		8 mm thermal break	- 0.1
		12 mm thermal break	- 0.2
		20 mm thermal break	- 0.3
		32 mm thermal break	- 0.4

C-3.16 Typical surface resistance values

Position	Walls $R_{surface}$ (m^2K/W)	Roofs $R_{surface}$ (m^2K/W)	Floors $R_{surface}$ (m^2K/W)
External	0.06	0.04	0.04
Air space (Also check Section 0 for other values)	0.18	0.16 (flat) 0.18 (pitched)	0.16
Internal	0.1	0.14	0.14

C-4 Calculation Examples for Heat Transfer through Building Elements

C-4.1 Heat flow through walls and roofs

The ISO 6946: 2017 standard provides a calculation method that is valid for most building components (walls and roofs).

For the case of a homogenous component, the method assumes each layer to have its own resistance. The arithmetic total of all resistances provides the overall resistance of the component.

Except for components consisting entirely of homogeneous layers (for which the upper and lower limits are equal) the true thermal resistance of a component is between these two limits. ISO 6946 specifies use of the arithmetic mean of the two limits provided that their ratio does not exceed 1.5.

For both cases, the appropriate external and/or internal surface resistances due to convection and radiation need to be added (see Table 0).

The following equations are used to calculate the resistance of a solid material and the U-values (ISO 6946:2017):

$$\mathbf{R = d/\lambda}$$

and

$$\mathbf{U = 1/R}$$

The thermal capacity of the wall is calculated for the aggregate sum of wall layers for the first 100 mm of the wall on the side of the zone under consideration or until reaching an insulating layer ($\lambda < 0.08$) or up to the centre of the wall's thickness, whichever is reached first, using the equation:

$$\mathbf{\kappa_m = \rho \times d \times c}$$

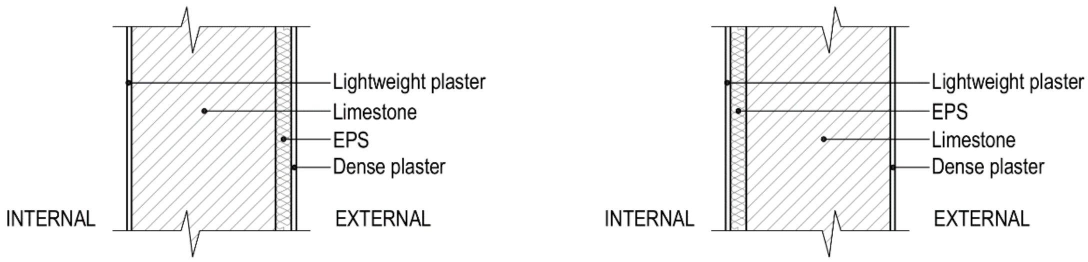
C-4.2 Example calculation of U-value for a homogenous wall

A component wall consists of the following layers and their respective physical characteristics.

Material	d (m)	λ (W/m K)	ρ (kg/m³)	c_p	Source
Soft limestone	0.18	1.1	1800	1000	Section 0
EPS insulation	0.01	0.04	15	1300	Section 0
External dense plaster	0.006	0.57	1300	1000	Section 0
Internal lightweight plaster	0.006	0.18	600	1000	Section 0

Calculate the overall U-value of the wall, assuming that it is exposed to the external on one side only.

Also, calculate the effective thermal capacity for the case when the insulation layer is placed on the outer side of the wall (Case A) and when it is placed on the inner side of the wall (Case B).



Case A Case B

Solution:

In order to calculate the overall resistance of the wall, one may follow the following steps:

1. The resistance for each layer is calculated separately.
2. The internal surface resistance is added.
3. The external surface resistance is added.
4. The sum of all resistances is calculated.
5. The inverse of the sum of all resistances gives the overall U-value.

Material	d (m)	λ (W/m K)	R (m²K/W)
External surface resistance			0.06
6mm external rendering	0.006	0.57	0.011
10mm EPS insulation	0.01	0.04	0.4
180mm soft limestone	0.18	1.1	0.16
6mm internal plaster	0.006	0.18	0.033
Internal surface resistance			0.1
Total R (m²K/W)			**0.764**
Overall U-value (W/m²K) = 1/R			**1.31**

In order to calculate the effective thermal capacity, one may follow the following steps:

1. Identify the layers starting from the internal side of the wall until the total thickness is 100 mm, or the mid-point of the component is reached, or a layer of insulation is encountered ($\lambda < 0.08$ W/mK).
2. Find the density and heat capacity for each layer.
3. Calculate the effective thermal capacity of each layer.
4. Make the arithmetical sum of all thermal capacities.

Case A: Insulation is on the outer side of the wall

Looking at the wall from inside, the layers are presented in the table below in order. Clearly, the overall thickness of the wall (202 mm) is more than 100 mm. Therefore, only two options remain, either to calculate κ_m for the first 100 mm or until an insulating layer is reached. Given that the insulating layer is on the outside, then for this case one would calculate κ_m by considering the internal plaster (6 mm thick) and part of the wall's thickness up to 94 mm, thus making the total 100 mm.

Material	d (m)	ρ (kg/m³)	c_p (kJ/kg K)	λ (W/m K}	κ_m (MJ/m²K)
6mm internal plaster	0.006	600	1000	0.18	3.6
180mm soft limestone	0.094	1800	1000	1.1	169.2*
10mm EPS insulation	0.01	15	1300	0.04	---
6mm external rendering	0.006	1300	1000	0.57	---
Total κ_m (MJ/m²K)					**172.8**

* The thickness used in the calculation is 94 mm, which together with the 6 mm internal plaster makes a total of 100 mm.

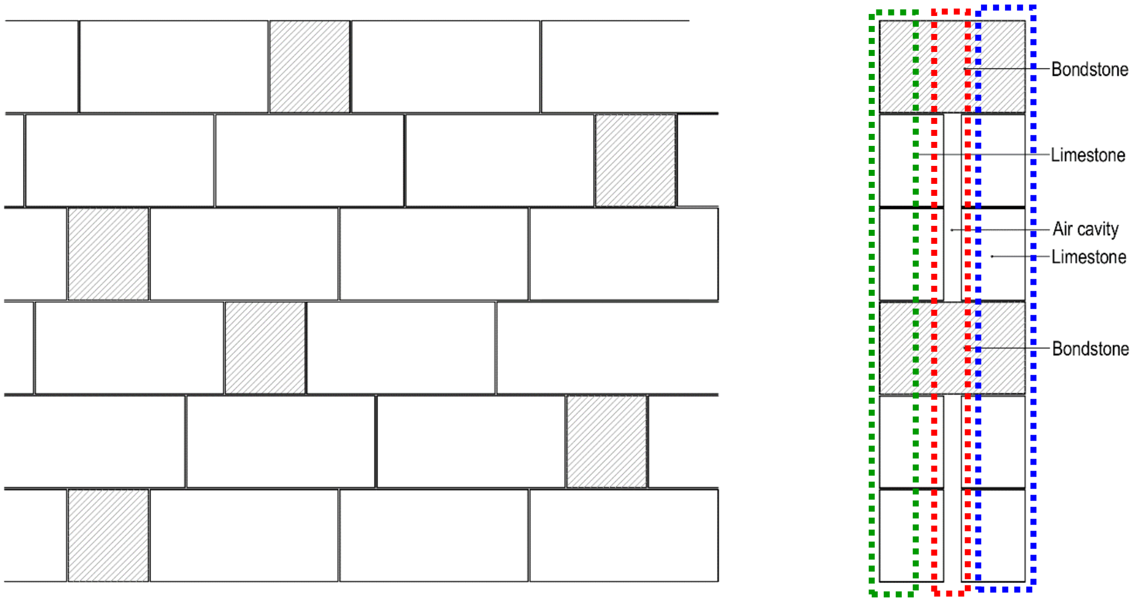
Case B: Insulation is on the inner side of the wall

For this case, only the internal plaster layer will count towards κ_m, because an insulating layer with $\lambda<0.08$ W/m K has been encountered.

Material	d (m)	ρ (kg/m³)	c_p (kJ/kg K)	λ (W/m K}	κ_m (kJ/m²K)
6mm internal plaster (gypsum board)	0.006	600	1000	0.18	3.6
10mm EPS insulation	0.01	15	1300	0.04	
180mm soft limestone	0.18	1800	1000	1.1	
10mm external rendering	0.01	1300	1000	0.57	
Total κ_m (MJ/m²K)					**3.6**

C-4.3 Example calculation of U-value for a composite wall

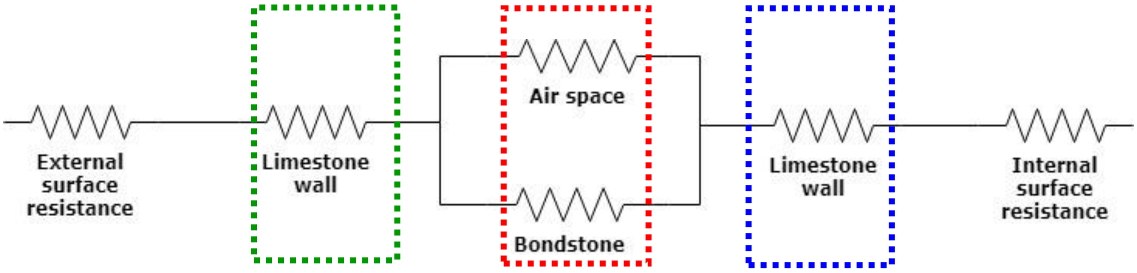
Calculate the overall U-value of a double leaf limestone wall with 50 mm air space and having 10% bond-stone. Assume that the wall is exposed to the external on one side only.



ELEVATION SECTION

Solution:

Lower resistance:



The lower resistance diagram above demonstrates the different resistance layers of the composite wall. In the middle, the air space is occupied by 10% bond-stone. The combined resistance within this layer is that of two resistances in parallel.

The combined resistance of the air space is found using the equation:

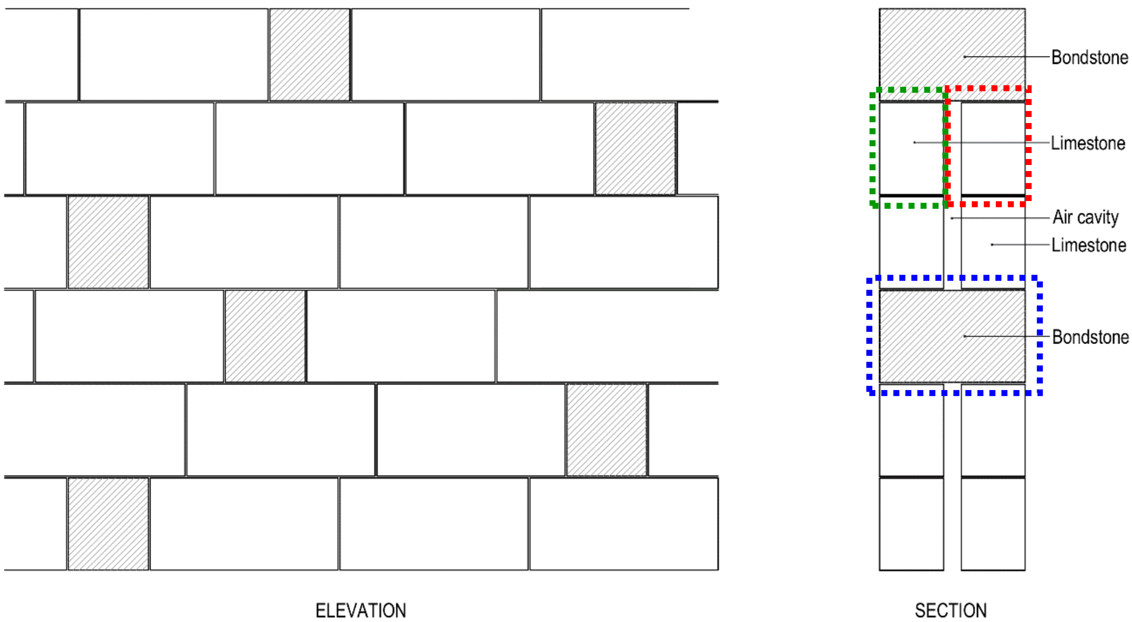
$$R_{combined} = \frac{1}{\frac{Fstone}{Rstone} + \frac{Fair}{Rair}}$$

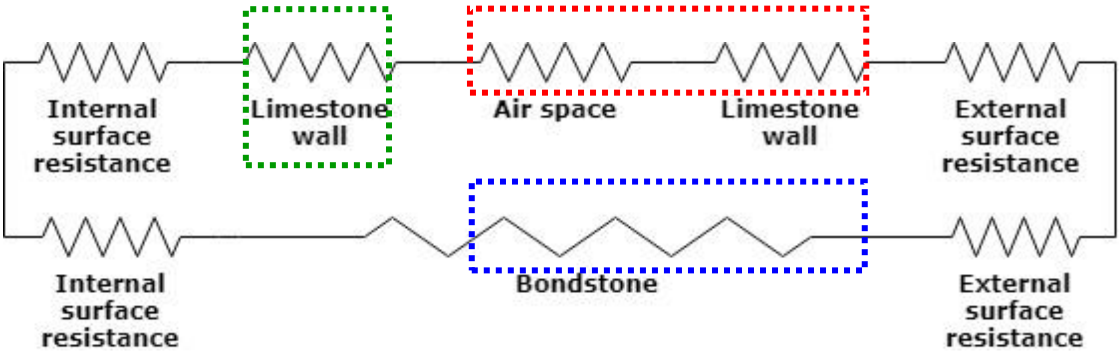
Where F is the surface area ratio occupied by the specific layer or fluid.

In this case $F_{stone} = 0.1$ and $F_{air} = 0.9$

Material	d (m)	λ (W/m K)	R (m²K/W)
External surface resistance			0.06
180mm soft limestone	0.18	1.1	0.16
90% air space			$\frac{1}{\frac{0.1}{0.045}+\frac{0.9}{0.18}}$
10% bond-stone	0.05	1.1	
180mm soft limestone	0.18	1.1	0.16
Internal surface resistance			0.1
Lower R value (m²K/W)			**0.618**

Upper resistance:





The upper resistance diagram above demonstrates the different resistance layers of the wall. The wall is modelled as two parallel resistances, whereby the first one includes the air space, which takes up 90% of the surface area within the air gap, while the second one considers the full length of the bond-stone from one end to the other and this occupies 10% of the total surface area. The calculations of R for each branch are shown below.

Material	d (m)	λ (W/m K)	R (m²K/W)
Internal surface resistance			0.1
180mm soft limestone	0.18	1.1	0.164
Air space			0.18
180mm soft limestone	0.18	1.1	0.164
External surface resistance			0.06
First branch R value (m²K/W)			**0.668**

Material	d (m)	λ (W/m K)	R (m²K/W)
Internal surface resistance			0.1
410mm soft limestone	0.41	1.1	0.37
External surface resistance			0.06
Second branch R value (m²K/W)			**0.533**

$$\textbf{Upper } R_{combined} = \frac{1}{\frac{0.9}{0.668}+\frac{0.1}{0.533}} = \mathbf{0.651}$$

Before applying the mathematical average of the lower and upper R-values, one needs to check that the ratio between those two figures is lower than 1.5.

Ratio $R_{upper} : R_{lower}$ = 0.651/0.618 = 1.053 < 1.5

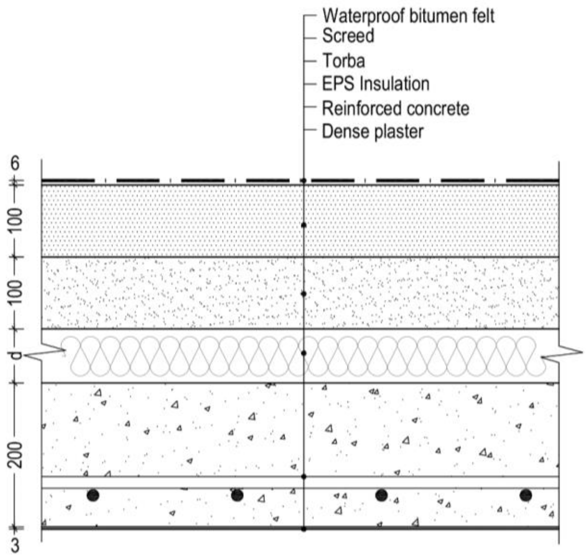
Therefore, the overall R = (0.651 + 0.618)/2 = 0.6345

U_{wall} = $1/R_{overall}$

U_{wall} = 1.57 W/m²K

C-4.4 Example calculation for minimum insulation thickness of a roof

Find the minimum thickness of EPS insulation material that needs to be placed on a flat roof to abide by the minimum Technical Document F U-value of 0.4 W/m²K.



Solution:

The layers of the roof and their respective R values are calculated in the table below. The missing thickness of the EPS insulation may be calculated, starting from a U-value of 0.4 W/m²K, as follows:

1. Determine R for each layer, as shown for each row in the table below.
2. Calculate the sum of all resistances R.

Material	d (m)	λ (W/m K)	R = d/ λ (m²K/W)	Source
Minimum overall U-value from Technical Document F (W/m²K)				**0.4**
		Total R (m²K/W)	**2.5**	
External surface resistance			0.04	Section 0
Water-proof bitumen felt	0.006	0.23	0.026	Section 0
Screed	0.1	0.41	0.244	Section 0
Torba	0.1	0.8	0.125	Section 0
EPS Insulation	**d**	0.04	d/0.04	Section 0
Reinforced concrete 2% steel	0.2	2.5	0.08	Section 0
Plaster (dense)	0.003	0.57	0.005	Section 0
Internal surface resistance			0.14	Section 0
Sum of all R's			0.66 + d/0.04	

3. The inverse of the total R should be equal to the required U-value of 0.4, as shown below:

$$\frac{1}{(0.66 + \frac{d}{0.04})} = 0.4$$

d = 0.0736 m or the nearest higher standard thickness available

C-5 Simplified Calculation Examples for Overshading Factors on Building Envelopes and Fenestration (SBEM, 2012)*

While it is well known that the effect of shading varies with the apparent movement of the sun, requiring more overshading in summer and little to no overshading in winter, early design of buildings may require an overall overshading factor for preliminary calculations of solar gains. This section details the method to be used for calculating the annual average overshading factors due to horizontal overhangs or vertical stationary fins.

One can find easy internet links to have a more detailed idea of the overshading

The overshading factor f_{sh}, also known as the shading reduction factor ranges between **1 for no shading and 0 for fully shaded**. However, in practice f_{sh} is hardly lower than 0.3, because the diffuse component of solar radiation cannot be fully blocked by fixed overhangs or vertical fins, given that it reaches the fenestration or building element from different sky directions.

C-5.1 Simplified calculation of overshading factor from overhangs

Fixed horizontal overhangs create shadows on both opaque and transparent building elements. The simplified approach to calculate this factor is based on a number of assumptions:

1. The reference point for overshading calculation is taken as the centre point of the building element under consideration.
2. Overshading calculations are only considered on the plane perpendicular to the building element.
3. The orientation of the building element is known to the nearest cardinal or ordinal direction (i.e. N, NE, E, SE, S, SW, W and NW).

The method used require the determination of the vertical overhang angle α subtended between the overhang and the centre of the building element, as shown in the example below. The overshading factor is then determined from the relevant table below using interpolation*.

* *Method follows the Simplified Building Energy Model for Malta (SBEMmt) Technical Manual , 2012, as originally reported in the UK SBEM Technical Manual, https://www.uk-ncm.org.uk/filelibrary/SBEM-Technical-Manual_v5.2.g_20Nov15.pdf*

Example 1: Determine the overshading factor of an overhang on the glazed window as shown in the figure below.

Solution:
Step 1: Find the overhang angle α
tan α = 0.6 / 1.4
α = 23.2°

Step 2: Use interpolation from the table below to find the overshading factor for the correct orientation of the building element under consideration.

Interpolating between overhang angle of 0 and 30° for a South facing building envelope, one gets

$$f_{sh} = 0.73 + \frac{(1-0.73)*(23.2-30)}{(0-30)}$$

$$f_{sh} = 0.79$$

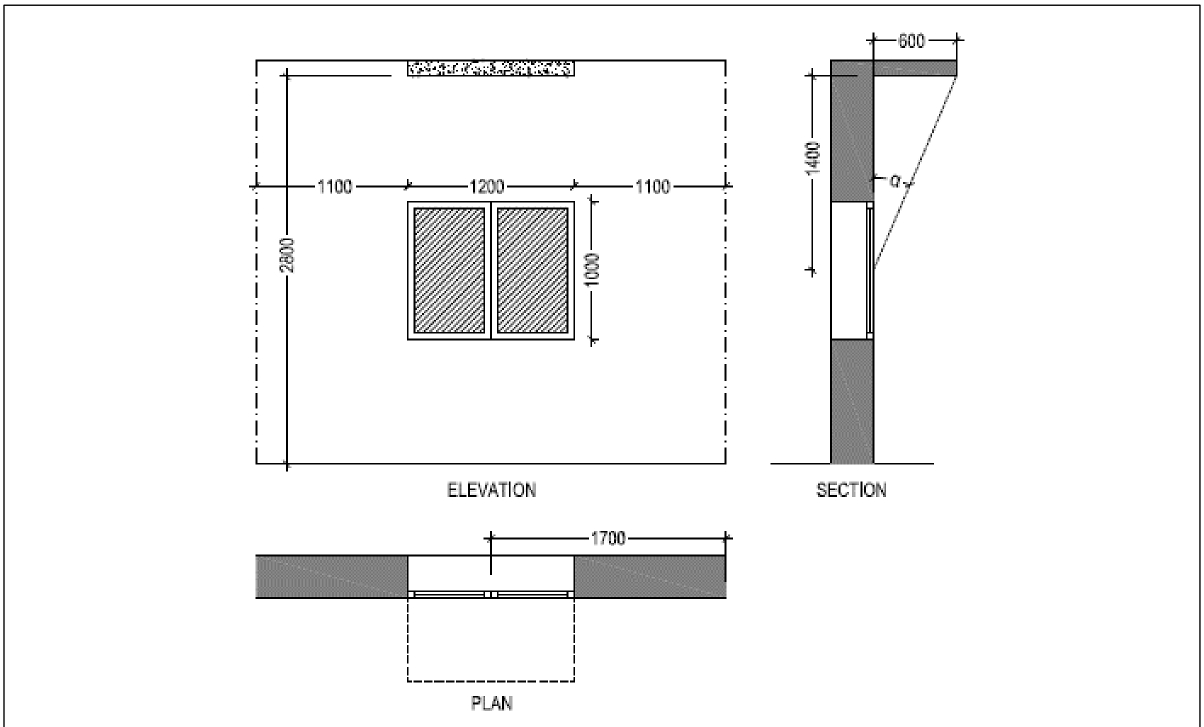


Table to be used for determining the overshading factor for **overhang** on building envelopes

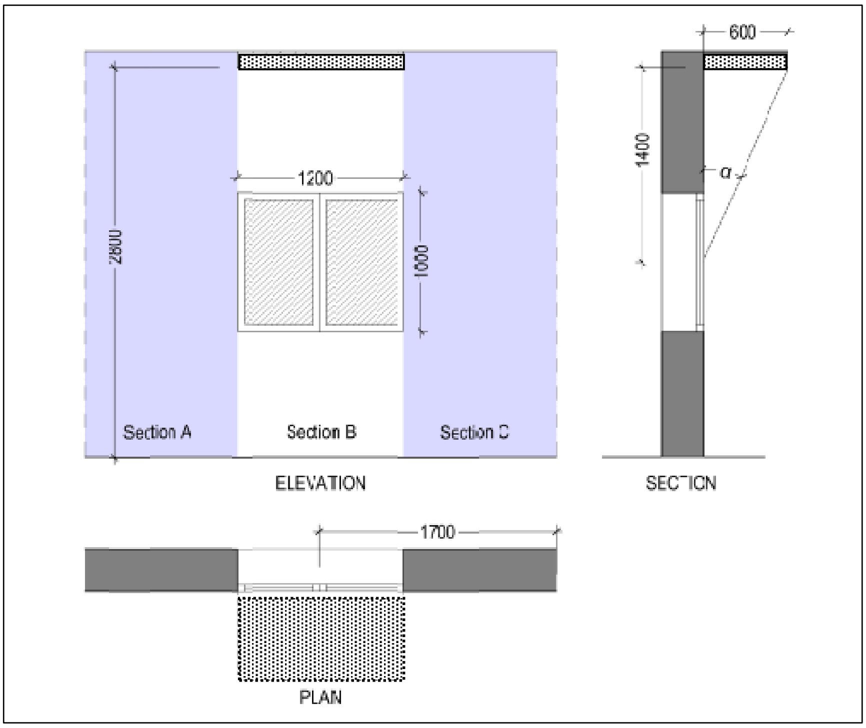
Overhang angle α	South	East/West	North
0°	1	1	1
30°	0.73	0.73	0.71
45°	0.58	0.58	0.56
60°	0.4	0.41	0.4

The overshading factors due to the overhang provided in the table above apply to Malta at Latitude of 36°.

Example 2: Using the example above, determine the overshading factor for the wall.

Solution:

It is noted that the overhang does not cover the whole width of the wall. Therefore parts of the wall on either sides of the window will have an overshading factor of 1, i.e. no shading. Hence, one should sub-divide the wall into sections, work each part separately and then determine the weighted overshading factor average based on the corresponding wall area of each section.



Step 1:

Determine the areas and overshading factors for Sections A and C.

Section A: A_A = 3.08 m², $f_{sh,A}$ = 1

Section C: A_C = 3.08 m², $f_{sh,C}$ = 1

Step 2:

Determine the area and overshading factor for Section B.

Given that the window was placed in the middle of the wall, the overshading factor for this part of the wall is equal to that determined for the window in Example 1.

Section B: A_B = 3.36 m², $f_{sh,B}$ = 0.79

Step 3:

Determine the weighted average of the overshading factor based on individual areas of each section.

$$f_{sh,\,overall} = \frac{3.08*1+3.36*0.79+3.08*1}{(3.08+3.36+3.08)}$$

$f_{sh,\,overall}$ = 0.93

N.B. For cases where there is a door in Section B of the wall, the overshading calculations of the door DO NOT correspond to those of that section of the wall, because the door would not be at the centre of the wall. For that case, each calculation has to be carried out separately for the door using its centre point, and for the wall using its centre point.

C-5.2 Calculation of overshading factor from vertical fins

Similar to the calculations of overshading factors for overhangs, the impact of overshading from vertical fins is calculated using the centre point of the relevant building element and the edge of the vertical fin, connected on a horizontal plane.

Example 3:
Determine the overshading factor of a vertical fin on the glazed window as shown in the figure below.

Solution:

Step 1:
Find the subtended vertical fin angle β

tan β = 0.6 / 1.7
β = 19.44°

Step 2:
Use interpolation from the table below to find the overshading factor due to vertical fin for the correct orientation of the building element under consideration.

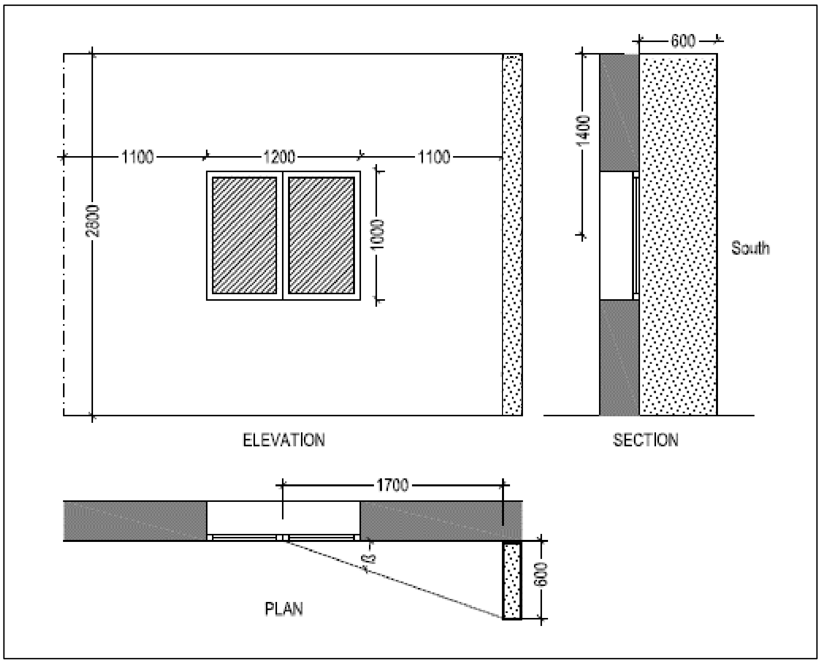


Table to be used for determining the overshading factor for **vertical fins** on building envelopes.

Vertical fin angle β	South	East/West	North
0°	1	1	1
30°	0.94	0.93	1
45°	0.84	0.85	1
60°	0.72	0.76	1

Interpolating between vertical fin angle of 0 and 30° for a South facing building envelope, one gets

$$f_{sh} = 1 + \frac{(19.44-0)*(0.94-1)}{(30-0)}$$

$$f_{sh} = 0.96$$

N.B. For cases where the vertical fin does not have the same vertical dimension as the building element, the calculated overshading factor on the building element shall follow the method explained in Example 2, above.

For building envelopes that have more than one external shading element, the combined overshading factor is the multiplication of the individual overshading factors.

Example 4:
Determine the combined overshading factor on the glazed window of Example 1 (overhang) and Example 2 (vertical fin).

Solution:
From Example 1, the overshading factor due to the overhang was found to be 0.79.
From Example 3, the overshading factor due to the vertical fin was found to be 0.96.
The combined overshading factor = 0.79 * 0.96 = 0.75

C-5.3 Correction to U_{glass} value due to glazed fenestration frame (SBEM, 2012)*

Example 5:
Calculate the corrected U_{glass} value of a 4mm clear single glazed window with an uninsulated aluminum window frame.

Solution:
Find the U_{glass} value corresponding to clear single glazing from Section 8.14, which is 5.75 W/m²K
Find the correction factor corresponding to an uninsulated aluminum frame from Section 8.15 under Window/Metal/No thermal break, which is +0.3
Therefore the corrected U_{glass} value = 5.75 + 0.3 = 6.05 W/m²K.